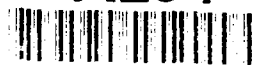AD-A254 455

Technical Report 954

Human Factors Research in Aircrew Performance and Training: 1986-1991

Final Summary Report

D. Michael McAnulty, editor
Anacapa Sciences, Inc.

July 1992

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United States Army Research Institute
for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction
of the Deputy Chief of Staff for Personnel

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13. ABSTRACT (Maximum 200 words)

This report presents summary descriptions of the research performed by Anacapa Sciences, Inc., for the U.S. Army Research Institute for the Behavioral and Social Sciences Fort Rucker Field Unit. This effort was entitled "Human Factors Research in Aircrew Performance and Training." From 9 October 1986 to 31 December 1991, Anacapa personnel worked on 42 research projects and 20 technical advisory services in emerging aviation systems design, manpower and personnel programs, aviator training, and aviation safety research. The report also describes research and development projects that were conducted under 17 subcontracts to Anacapa Sciences. These descriptions contain (a) a background section that describes the rationale for the project and specifies the research objectives; (b) a research approach section that describes the tasks and activities required to meet the project objectives; and (c) a work completed section that may include research findings or, in the case of developmental activities, a description of the research products.

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D. Michael McAnulty, editor
Anacapa Sciences, Inc.

Field Unit at Fort Rucker, Alabama
Charles A. Gainer, Chief

Training Systems Research Division
Jack H. Hiller, Director

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Rucker Field Unit is contributing to the effectiveness of Army aviation by conducting a comprehensive human factors research program in support of aircrew performance and training. This program encompasses the full scope of Army aviation with projects in support of (a) emerging Army aviation systems, (b) aviation manpower and personnel programs, (c) aviator training programs, and (d) aviator safety programs.

This report summarizes research performed and products developed in all four of the above areas between 9 October 1986 and 31 December 1991 by Anacapa Sciences, Inc. The report also summarizes technical advisory services performed by Anacapa Sciences personnel and subcontracts performed by other organizations during the contract period.

The projects in emerging systems and aviation safety are conducted within the mission of the MANPRINT Division at ARI. The projects in manpower and personnel are conducted within the mission of the Manpower and Personnel Research Division at ARI. Finally, the aviator training projects are conducted within the mission of the Training Systems Research Division at ARI. Specific taskings are identified for each project or research area and the utilization of the research findings or products is described in the summaries.

This report is designed to meet two important objectives: First, it provides a summary of research progress and accomplishments to U.S. Army weapon system managers, manpower and personnel planners, and training system developers and managers in their respective areas of responsibility. Second, it provides summary information to behavioral scientists who may be working on similar applied research issues, either within the Department of Defense or within other governmental, industrial, or university organizations.

EDGAR M. JOHNSON
Technical Director

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING:
1986-1991
FINAL SUMMARY REPORT

<u>EXECUTIVE SUMMARY</u>

Requirement:

Anacapa Sciences, Inc., has provided collocated re-
search support to the U.S. Army Research Institute for the
Behavioral and Social Sciences Fort Rucker Field Unit since
1981. The Fort Rucker program supports the full range of
Army aviation research requirements with projects that ad-
dress issues in emerging aviation systems, aviation manpower
and personnel, aviation safety, and aviator training. This
final summary report describes the projects and technical
advisory services conducted by Anacapa Sciences researchers
between October 1986 and December 1991 in support of the
Fort Rucker program. In addition, it describes other re-
search projects conducted for the Fort Rucker Field Unit
during the same time period under subcontract to Anacapa
Sciences. The specific requirements that led to the initia-
tion of each research project are discussed in the individ-
ual summaries.

Procedure:

There are substantial differences in the methods that
were employed in the individual Anacapa projects, in the
technical advisory services, and in the subcontract proj-
ects. In some cases, the research approach was a scientific
experiment in which selected variables were controlled,
manipulated, and measured. In other cases, the research
approach was a set of analytical or product development
tasks. The specific research methods used in each project
and the technical advisory service are described in the
individual summaries.

Findings:

The research projects summarized in this report were
conducted in all four domains of the Fort Rucker Field Unit
research program.

The report is divided into three major sections. The
first contains complete summaries of the 19 research proj-
ects and 2 technical advisory services conducted by Anacapa

Sciences personnel during the current contract year. Eight of the current-year projects were in the area of emerging systems, two were in manpower and personnel, three were in aviation safety, and six were in aviation training. Five of the six training projects addressed issues in flight simulation. Many of the projects completed during the final contract year were initiated during previous contract years; some of the long-term projects were conducted throughout the entire contract.

The second section contains brief summaries of the 23 projects and 18 technical advisory services completed by Anacapa Sciences personnel during the 4 previous contract years. Six of the previous contract-year projects were in the area of emerging systems, 1 was in manpower and personnel, 1 was in aviation safety, and 15 were in aviation training. The final section describes the 17 subcontracts completed during the current and previous contract years.

Utilization of Findings:

The results and recommendations of many of the projects, technical advisory services, and subcontracts will be directly implemented in the design of new aviation systems, in the selection and management of aviation personnel, in aviation safety programs, and in aviation training at the U.S. Army Aviation Center, Fort Rucker, Alabama, and in Army aviation units around the world. This report provides Army systems managers, manpower and personnel planners, training system developers and managers, and researchers working in related fields with a summary of the research activities in their respective areas of interest.

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING:
1986-1991
FINAL SUMMARY REPORT

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AA	Active Army
AAA	Army Audit Agency
AAWWS	Airborne Adverse Weather Weapon System
AHP	Army Heliport
AHT	Automated Hover Trainer
AIRNET	Aviation Networked Simulator
ANVIS	Aviator Night Vision Imaging System
AO	Aerial Observer
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ARIARDA	Army Research Institute Aviation Research and Development Activity
ARMS	Aviation Resource Management Survey
ARTEP	Army Training and Evaluation Program
ASMIS	Army Safety Management Information System
ATB	Aviation Training Brigade
ATHS	Airborne Target Handover System
ATM	Aircrew Training Manual
AutoBOB	Automated Version of the Blueprint of the Battlefield
AVCATT	Aviation Combined Arms Tactical Trainer
AVNOAC	Aviation Officer Advanced Course
AVSCOM	Aviation Systems Command
AWC	All Weather Cockpit
BMQ	Basic Mission Qualification
CAD	Computer Aided Design
CBI	Computer-Based Instruction
CMI	Contractor Mission Instructor
CMS	Combat Mission Simulator/Cockpit Management Systems
CO	Commissioned Officer
CPG	Copilot/Gunner
CSRDF	Crew Station Research and Development Facility
DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DCD	Directorate of Combat Developments
DCSOPS	Deputy Chief of Staff for Operations
DES	Directorate of Evaluation and Standardization
DOTD	Directorate of Training and Doctrine
DOTS	Department of Tactics and Simulation
DRC	Dynamics Research Corporation
EAO	Enlisted Aerial Observer
EAOC	Enlisted Aeroscout Observer Course
EGA	Enhanced Graphics Adapter
ETM	Emergency Touchdown Maneuver
FARP	Forward Arming and Refueling Point
FAST	Flight Aptitude Selection Test
FLIR	Forward-Looking Infrared
FORSCOM	Forces Command

FORCE   Force Development Analysis
FRED   Fully Reconfigurable Experimental Device
FS   Flight Simulator
FWS   Flight and Weapons Simulator
FY   Fiscal Year
HARDMAN   Hardware Versus Manpower
HF   Human Factors
HMD   Helmet-Mounted Display
HSD   Horizontal Situation Display
HUD   Head-Up Display
IERW   Initial Entry Rotary Wing
IFR   Instrument Flight Rules
IG   Image Generator
IP   Instructor Pilot
IPC   Instructor Pilot Course
LAFS   Light Airborne FLIR Systems
LHX   Light Helicopter Family
LOD   Level of Detail
LOS   Line of Sight
MANPRINT   Manpower and Personnel Integration
M-CON   Manpower Constraints
MER   Manpower Estimate Report
MITAC   Map Interpretation and Terrain Analysis Course
MMI   Military Mission Instructor
MOS   Military Occupational Specialty
MOU   Memorandum of Understanding
MPT   Manpower, Personnel, and Training
MTP   Mission Training Plan
NASA   National Aeronautical and Space Agency
NFAST   New Flight Aptitude Selection Test
NG   National Guard
NOE   Nap of the Earth
NVG   Night Vision Goggles
OAG   Overall Average Grade
OWL   Operator Workload
PC   Personal Computer/Peer Comparison
P-CON   Personnel Constraints
PNVS   Pilot Night Vision System
POI   Program of Instruction
RAM   Reliability, Availability, and Maintainability
REFORGER   Return of Forces to Germany
RFAST   Revised Flight Aptitude Selection Test
S&T   Selection and Training
SCAD   Soldier Characteristics Availability Database
SCTB   Simulator Complexity Test Bed
SME   Subject Matter Expert
SOA   Special Operations Aircraft
SOAR   Special Operations Aviation Regiment

SORD	Systematic Organizational Design
SP	Student Pilot
SPARC	System Performance and RAM Criteria
SRL	Systems Research Laboratory
STRAC	Standards in Training Commission
STRATA	Simulator Training Research Advanced Testbed for Aviation
TADS	Target Acquisition and Detection System
TAWL	Task Analysis/Workload
T-CON	Training Constraints
TEA	Training Effectiveness Analysis
TER	Transfer Effectiveness Ratio
TOSS	TAWL Operator Simulation System
TOT	Transfer of Training
TRADOC	Training and Doctrine Command
TRS	Training Research Simulator
TSM	Training System Manager
UH1FS	UH-1 Instrument Flight Simulator
UH1TRS	UH-1 Training Research Simulator
UMSDC	Unscheduled Maintenance Sample Data Collection
USAALS	U.S. Army Aviation Logistics School
USAAVNC	U.S. Army Aviation Center
USAR	U.S. Army Reserve
USAREUR	U.S. Army, Europe
USASC	U.S. Army Safety Center
VGA	Video Graphics Array
WOC	Warrant Officer Candidate

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1986-1991 FINAL SUMMARY REPORT

INTRODUCTION

Anacapa Sciences, Inc., has provided collocated research support to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, under a series of contracts that began on 1 September 1981. The current contract (No. MDA903-87-C-0523) requires the submission of four Annual and one Final Summary Report of research activities. This report is the final summary of activities on the current contract and is divided into three sections: current contract year research conducted by Anacapa Sciences personnel, previous contract year research conducted by Anacapa Sciences personnel, and work conducted under subcontract.

The first section describes in detail the Anacapa research project activities and achievements during the period from 9 October 1990 to 31 December 1991. Throughout the report, this period is referred to as the current contract year. Ten of the research summaries in this section describe individual projects that Anacapa Sciences personnel have worked on during the current contract year. Four of the summaries describe research areas that are divided into nine discrete projects. Finally, two summaries describe technical advisory services, which are extensive research support provided to projects that are directed by ARIARDA personnel.

Most of the summaries in this section follow the same general format. Each summary begins with a background section that presents information needed to understand the requirement for the project. The background may include a brief review of the relevant research literature or describe the critical events that led to the initiation of the project or technical advisory service. Where appropriate, the relationship between specific projects in a research area is discussed.

When the need for the research cannot be clearly inferred from the background information, a statement of need or definition of the research problem is presented. This is followed by a concise statement of the project or research area objectives. Next, the research approach section presents a description of the activities that were planned to accomplish the research objectives. For some projects, the research approach is a scientific experiment in which selected variables are controlled, manipulated, and measured. For other projects, the research approach is a set of analytical or product development tasks.

The research approach is usually followed by one or more sections that describe the work completed on the project and the research findings or, in the case of product development efforts, a description of the research products. In the technical advisory services summaries, the research approach is followed by a description of the services provided by Anacapa personnel. The final section of each summary may also describe additional research requirements, if any.

The project summaries are presented in four content categories that reflect the research domains at ARIARDA. This organization is intended to assist the reader in locating a specific project summary within a research domain or in finding summaries that are closely related in terms of content.

The first five summaries describe eight projects in emerging aviation systems design. The sixth summary describes two projects in manpower and personnel research. The next three summaries describe three projects in aviation safety research. The next five summaries describe six aviation training research projects. The last two summaries describe the two technical advisory services that supported ARIARDA training research projects. The number of projects assigned to the four categories is not necessarily in proportion to the emphasis placed on each research domain.

Although each summary identifies the project director(s) or technical advisor, the Anacapa approach to research employs a team concept. This approach provides the optimum utilization of each scientific staff member's skills and ensures coordination among closely related projects.

The second section begins with a summary of all the research activities conducted during the first four years of the contract. The third section also begins with a brief introductory statement about the subcontracts awarded by Anacapa Sciences at the direction of ARIARDA.

DEVELOPMENT OF A TASK ANALYSIS/WORKLOAD OPERATOR SIMULATION SYSTEM (TOSS)

Ms. Laura A. Fulford, Project Director

Background

Anacapa Sciences researchers, under a previous contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, developed a task analysis/workload (TAWL) methodology for predicting operator workload during the conceptual phase of system development. The methodology was first applied to the Army's Light Helicopter Family (LHX) aircraft (McCracken & Aldrich, 1984). Subsequently, Anacapa personnel refined the mission/task/workload analysis methodology and produced operator workload prediction models for the AH-64A (Szabo & Bierbaum, 1986), the UH-60 (Bierbaum, Szabo, & Aldrich, 1989), and the CH-47 aircraft (Bierbaum & Aldrich, 1990). Each of the original workload prediction models was programmed in FORTRAN 77 on a Perkin-Elmer 3210 computer.

Need

The FORTRAN 77 programs for the LHX, AH-64A, and UH-60 workload prediction models incorporated the model decision rules into the actual program code. Time-consuming recompilations of the programs were required to incorporate even minor changes in the models. A TAWL operator simulation system (TOSS) was needed to reduce the development time for implementing changes to models and creating new ones.

Objectives

The primary objective of this project is to develop a software system that (a) allows model changes without rewriting and recompiling the software, (b) executes any of the workload prediction models developed with the refined TAWL methodology, and (c) can be used directly by workload analysts. In addition, the software should run on widely available computers and be written in a language that is easy to modify.

Approach

The TOSS software was designed to store all model information peculiar to a specific system in computer data files. The design enables the user to change an existing model simulation by changing data files, thereby eliminating the need to alter the program to incorporate model changes. By creating a new set of data files, new models can be developed. Because entering model data using a standard text editor is time consuming and subject to errors, a data base management system with specialized routines was designed for entering and updating all of the data used·in the workload prediction models. Each specialized routine features error checks to ensure the validity of the data. The most critical data is protected by automatic backup procedures. Finally, a simple and consistent user interface, based on the user's perspective of the methodology, was developed so that workload analysts could directly manipulate the software. The software system was written in the Turbo Pascal programming language and runs on any IBM AT compatible computer.

Work Completed

During the previous contract years, initial versions of TOSS were developed and extensively modified. The initial development of TOSS versions 2.0 and 3.0 are discussed in detail in Fulford (1990). The final stages of version 3.0 and the initial development of version 4.0 are discussed in detail in Fulford (1991). Work completed during the final contract year included modifications to the TOSS 4.0 software, preparation of a TOSS 4.0 User's Guide, and the presentation of papers about TCSS 4.0.

TOSS 4.0

During the final contract year, five modifications were incorporated into version 4.0. First, additional error-detection routines were implemented throughout the software. Second, the page length for the output created during segment simulation and report generation is now user-defined. Third, the numerical output files can contain page headings depending on the user's preference. Fourth, the simulation procedure was modified so that if the escape key is pressed while segments remain in the execution list, the user is asked whether to execute the remaining segments or to return to the segment listing.

Finally, the simulation of function interrupts was revised. When a function is reinstated after being interrupted, discrete fixed tasks that were being performed no longer continue from the time of suspension. Instead, the tasks are reset to start from their beginning when the function is reinstated. Furthermore, the start and finish times for all tasks that have not been simulated are incremented so that the original performance order specified in the decision rules is maintained.

User's Guide

On 14 December 1990, five copies of the draft User's Guide and software were delivered to ARIARDA for review. In February 1991, several changes were made to the text of the User's Guide to address the issues raised during the ARIARDA review. Furthermore, a flow chart of the processes that occur during segment simulation was developed to document the simulation procedures. The flow chart was included in the final version of the User's Guide. On 14 March 1991, 15 copies of the final version of the TOSS 4.0 User's Guide and software were delivered to ARIARDA. Submission of the copies completed work on the TOSS version 4.0 project.

Papers

A paper on the TAWL methodology (Hamilton & Bierbaum, 1990) and a demonstration of TOSS (Fulford, Hamilton, & Bierbaum, 1990) were presented at the 34th annual meeting of the Human Factors Society.

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THE AH-64 WORKLOAD PREDICTION MODEL

Dr. David B. Hamilton, Project Director

Background

The Army's Air/Land Battle 2000 scenario presents a high-threat environment that places heavy workload demands on the combat helicopter aircrew. To increase mission effectiveness in this environment, the latest Army helicopters are equipped with advanced technology. This technology includes electronic sensor capabilities that increase both the amount and fidelity of information available to the crew.

One example in the current U.S. Army inventory is the AH-64A Apache attack helicopter. It was the first Army aircraft equipped with flight and weapon systems that allow missions to be conducted at night and under adverse weather conditions. The increased mission capabilities of the AH-64A aircraft have dramatically increased the amount of information that the crew must process. The AH-64A is equipped with automated flight and combat (acquisition, targeting, and engagement) technology that is intended to reduce crew workload. In some instances, however, the technology has either increased workload or simply changed the nature of the task without decreasing workload. High workload, in turn, reduces mission effectiveness, increases system manning requirements, and increases the training necessary for acquiring and maintaining flight proficiency.

One reason that technology has failed to reduce workload in Army aircraft is that human factors concepts were not adequately considered during the early stages of system design. For example, many of the subsystems in the AH-64A were not integrated to simplify the man-machine interface and reduce workload. In the past, a methodology for assessing the workload demands of emerging aviation systems did not exist. However, researchers from the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) and Anacapa Sciences have developed a methodology for predicting the workload demands placed on crewmembers by the advanced technology proposed for the multipurpose lightweight helicopter, the LHX.

Recently, Anacapa researchers refined the LHX methodology to support its application in evaluating workload in existing or developmental weapon systems; the refined methodology is called the Task Analysis/Workload (TAWL) methodology (see Hamilton, Bierbaum, & Fulford, 1990). In

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addition, computer support for the methodology has been developed and named the TAWL Operator Simulation System (TOSS).

The methodology takes a multidimensional view of human capabilities that enables the system engineer to identify modifications that shift workload from one domain to another. *For example*, technology that reduces an aviator's need to maintain physical control of system functions often increases the aviator's role as a monitor. Thus, advanced technology may decrease psychomotor workload and increase cognitive workload. Because human cognitive ability is limited, system designers must avoid shifting all the workload associated with aircraft operations into the cognitive domain (or into any other single domain). Using the TAWL methodology, system engineers can better utilize crew capabilities and increase system effectiveness.

The Army is currently developing an improved AH-64 helicopter called the Longbow Apache. The man-machine interface will change substantially with the incorporation of two touch-screen multifunction displays and the removal of the majority of the switches and dials. The principal additions in the Longbow Apache will be the Airborne Target Handover System (ATHS) and the Airborne Adverse Weather Weapon System.

Need

The Army Aviation Systems Command (AVSCOM), St. Louis, Missouri, requested that ARIARDA apply the TAWL methodology to evaluate the workload in the AH-64A Apache and in the Longbow Apache currently being developed. In response to AVSCOM's request for support, ARIARDA tasked Anacapa to conduct the required research.

Research Objectives

The overall objective of the AH-64 workload prediction research is to determine the effect that advanced technology has on the workload of AH-64 attack helicopter crewmembers. The research is divided into the following three specific objectives:

- determine the workload for the current configuration of the AH-64A aircraft,
- predict the effect that Longbow design modifications will have on crew workload, and

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- identify the AH-64 mission functions and subsystems for which design modifications will be most beneficial in reducing crew workload.

Research Approach

The research for meeting these objectives is divided into the following three projects.

Development of the AH-64A Workload Prediction Model

The development of a model to predict workload for the AH-64A aircrew will be divided into four tasks. The initial task will be to enter the mission/task/workload analysis data developed under a previous project (Szabo & Bierbaum, 1986) into a computer data base. The second task will be to develop and enter the function and segment decision rules into the computer. Function decision rules specify the sequence and time for performing the tasks in each function. The segment decision rules specify the sequence, time, and interaction of the functions in each segment.

In the third task, the TOSS software will be utilized to automate the workload analysis. The computer program will use the function and segment decision rules to combine the tasks to form functions and, in turn, to combine functions to form segments. The computer program will simulate the sequence of tasks that each crewmember must perform to accomplish the mission. From this simulation, the program will generate total workload estimates for each of five workload components (visual, auditory, cognitive, psychomotor, and kinesthetic) by summing the individual workload ratings for all the tasks that are performed concurrently. The total component workload predictions will be generated for every half-second interval in the segment. The estimates of component workload will identify points on the mission timeline where excessive workload (i.e., overload) will occur. Thus, predictions of total workload associated with the performance of concurrent and sequential tasks in the AH-64A baseline configuration will be generated.

In the fourth task, the results of the simulation will be reviewed to identify and correct any errors in the task/workload analysis data base. In addition, AH-64A subject matter experts will review the computer simulation of the crewmembers' actions during each mission segment to ensure that the model conforms with typical crewmember actions.

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Validation of the AH-64A Workload Prediction Model

During the second project, the validity of the TAWL methodology and the AH-64A workload prediction model will be tested. The workload predictions yielded by the model will be evaluated by conducting part-mission and full-mission simulation research. In each instance, predictions of workload for specific tasks will be compared with objective measures of primary task performance, physiological measures of workload, and subjective measures of workload.

Finally, the results of the validation research will be used to refine the model. The research to validate the AH-64A model will not only establish the accuracy of the predictions of AH-64A workload prediction model, but will also establish the utility of the TAWL methodology for producing valid models of workload.

Development of the Longbow Apache Workload Prediction Model

During this project, the AH-64A computer model will be modified and exercised to predict how crew workload might be affected by the changes made to the Longbow model. The project consists of the following steps:

- establish a secure computer system for developing the model,
- identify the design changes that affect the operation of the system,
- conduct a task/workload analysis for each change,
- develop the function and segment decision rules for the changes,
- exercise the Longbow model to yield estimates of workload, and
- compare the estimates of workload for the AH-64A and Longbow configurations.

The results of this project will be used to estimate the differences in crewmember workload between the AH-64A and the Longbow Apache. The estimates, in turn, will assist design engineers in identifying the configuration of the AH-64A that produces lower workload.

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Work Completed

Development of the AH-64A Workload Prediction Model

Under the previous contract, Szabo and Bierbaum (1986) conducted a task/workload analysis of all phases of the AH-64A attack mission. Seven mission phases were identified and divided into 52 unique mission segments. The segments were further divided into 159 unique functions with 688 individual tasks necessary to the mission. Finally, the subsystem, crewmember, and duration for each task are identified.

During the first 3 years of the current contract, both the task/workload analysis and the decision rules were extensively reviewed and revised. A preliminary version of the computer model was developed using a Perkin-Elmer minicomputer and FORTRAN programming language. The model was later reprogrammed using the TOSS software and an IBM personal computer. The model was exercised to produce preliminary analyses of workload for each of the mission segments, which were reviewed to ensure that the computer model accurately simulated the mission. In some cases, the function and segment decision rules were revised. A review of graphs of the workload predictions revealed a number of inaccuracies in the decision rules. During the third and fourth contract years, the AH-64A model was revised to increase its accuracy. The changes included substituting interval rating scales for ordinal workload scales, revising the task/workload analysis, and revising the function and segment decision rules.

During the final contract year, improved modeling techniques were incorporated into the model, including the separation of the sensory and psychomotor workload of flying tasks for improved accuracy of simulation. The revised version of the model was prepared on computer media for delivery to ARIARDA.

Validation of the AH-64A Workload Prediction Model

During third contract year, a report (Hamilton, 1990) documenting the validation research approach was written and submitted to ARIARDA. The report called for the measurement of several objective and subjective measures of workload to be used as validation criteria. In addition, a request was prepared and submitted to Forces Command (FORSCOM) for support in validating the AH-64A model.

During the fourth contract year, the FORSCOM request for support of this research was denied. The reasons for the denial were discussed with FORSCOM personnel and another request for support was prepared with reduced requirements for person al and Combat Mission Simulator (CMS) resources. The revised research approach was submitted and an in-progress review of the validation research was conducted for ARIARDA approval. Subsequently, three sets of materials were prepared for the validation research. First, materials required to collect the National Aeronautics and Space Administration (NASA) Task Load Index (the subjective measure of workload) were adapted for the AH-64A simulation environment. Second, rating scales were drafted to evaluate aircrew performance during the AH-64A mission. Finally, the materials were compiled for developing equal-interval workload ratings scales based on a sample from the AH-64A pilot population. Also during the fourth contract year, alternative methods of obtaining physiological measures of workload were evaluated.

During the current contract year, all materials required to conduct the validation research was completed and the equipment for physiological measurement was acquired. However, the revised request for FORSCOM support was denied. Therefore, an alternative research approach was developed to utilize available equipment and personnel.

There were two objectives of the alternative validation research. The first objective was to test the materials, measures, and procedures developed for the original validation. The second objective was to provide an indication, however limited, of the validity of the workload prediction models developed using the TAWL methodology and TOSS software.

A computer program was developed that was similar to the programs currently in use in the Multi-Track Selection Tests compiled by ARIARDA. The program runs on IBM-compatible computers equipped with aircraft type foot pedals and hand controllers. The program measures the performance of subjects on any combination of four tasks: two different single-axis tracking tasks, one dual-axis tracking task, and a dichotic listening task. The program was used to create seven tasks that varied in workload.

Twenty AH-64A aviators were required to report for three 2-hour test sessions. During each test session the aviators performed three trials of the seven tasks. Measures of tracking and dichotic listening performance were recorded by the computer program. Three physiological measures of workload (heart rate variability, eye-blink, and respiration)

were recorded on videotape for later analysis. Finally, a subjective measure of workload, the NASA Task Load Index, was collected after each task.

Two analysts independently developed TAWL/TOSS workload prediction models for the seven experimental tasks. The predictions from each model were correlated with the measures of tracking and dichotic listening performance. The workload predictions were highly correlated (none less then .80) with each of the performance measures and the subjective workload ratings. These high correlations indicate that the predictions generated by the models have a high degree of validity. The methods, procedures, and results of the preliminary validation research were described in a research report and submitted to ARIARDA in December 1991.

Development of the Longbow Apache Workload Prediction Model

During the previous contract year, a secure computer system was established for developing the Longbow Apache workload prediction model. The major modifications to the Longbow Apache were identified, changes to the composite mission scenario resulting from the modifications were analyzed, and the additional segments needed to model the changes were identified.

During the current contract year, progress on the Longbow task/workload analysis was delayed because of work on higher priority projects.

Future Requirements

Development of the AH-64A Workload Prediction Model

During the contract, the AH-64A workload prediction model was substantially improved from the model described in the technical report by Szabo and Bierbaum (1986). Although the improved model is available to ARIARDA on computer media, the advances in the modeling techniques are not documented. To provide all researchers with full access to the model, the final version of the model and its predictions need to be described in a technical report.

Validation of the AH-64A Workload Prediction Model

Part- and full-mission validation research, as described in the in approach section of this report, needs to be

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conducted. Although the results from the preliminary validation research are encouraging, the task domain was limited and artificial. Validation research conducted in the AH-64A CMS should produce convincing evidence of the validity of the AH-64A workload prediction model and the TAWL methodology.

Development of the Longbow Apache Workload Prediction Model

A Longbow Apache workload prediction model needs to be developed as described in the approach section of this summary. The predictions of the model should be compared to the AH-64A model predictions to determine if the Longbow upgrades place unacceptably high workload on the system operators.

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OH-58D KIOWA WARRIOR TASK ANALYSIS

Mr. Carl R. Bierbaum, Project Director

Background

The enhanced mission capabilities of the armed OH-58D Kiowa Warrior aircraft have increased both the number of tasks that the crewmembers are required to perform and the amount of information that the crewmembers must process. Because of the increased workload, the Army decided to reevaluate the crew configuration of the aircraft. Accordingly, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) tasked Anacapa Sciences to perform a task/workload analysis of the OH-58D and to develop a computer model that predicts the workload associated with the various configurations of the armed OH-58D Kiowa Warrior aircraft.

Research Objective

The primary objective of the OH-58D workload prediction research is to determine the impact that the increased mission capabilities of the armed OH-58D has on the workload of the crewmembers. Specifically, the research is designed (a) to conduct a mission/task analysis of the armed OH-58D and (b) to determine the effects that various design modifications and mission changes have on the armed OH-58D crewmembers.

Research Approach

The research approach for meeting the objectives was the Task Analysis Workload (TAWL) methodology that was developed for the UH/MH-60 (Bierbaum & Hamilton, 1990a) and CH/MH-47 (Bierbaum & Hamilton, 1990b) research projects. The steps performed with the TAWL methodology are listed below:

- develop a mission scenario,
- divide the scenario into mission phases and segments,
- identify the functions in the mission segments,
- identify the tasks for each function,
- estimate the workload for each task,
- estimate the time required to perform each task,
- allocate the tasks and functions, and
- develop the workload prediction model.

Work Completed

The OH-58D task analysis and workload prediction model has been completed. The development steps are described in the following paragraphs.

Develop a Mission Scenario

The OH-58D mission scenario begins with a departure from an assembly area. The pilot flies contour and nap-of-the-earth (NOE) from the assembly area to the holding area where mission coordination is conducted. From the holding area, the crew performs an NOE movement to contact where battle area deployment is performed and target engagement functions occur. When the weapons are expended, the pilot departs the battle position and flies NOE to the forward arming and refueling point (FARP) to refuel and rearm the aircraft. The mission is conducted in optimal flight conditions (e.g., excellent weather conditions, no aircraft emergencies).

Divide the Scenario Into Mission Phases and Segments

The mission scenario was divided into six mission phases. A mission phase is a required, logical part of a mission that may be accomplished in several ways. Phases must be sequential to other phases and must be contiguous. Each of the six mission phases was subsequently divided into mission segments. A mission segment is defined as a major group of events that have definite start and end points during a mission phase. A total of 22 segments was identified in the mission phases. The mission phases and the number of segments are as follows:
- Departure - 2,
- Conduct Movement to a Holding Area - 4,
- Conduct Movement to Contact - 3,
- Move to and Occupy Battle Position - 3,
- Target Engagement - 5, and
- Return to Assembly Area - 5.

Identify the Functions in Each Segment

Each of the 22 segments was further divided into functions. A function is defined as a set of activities that must be performed either by an operator or by equipment to complete a portion of the mission segment. A total of 54 unique functions was identified for the 22 segments.

Identify the Tasks for Each Function

The 54 unique functions are further divided into a total of 166 tasks considered to be critical to the successful performance of the functions. Each task consists of a verb describing the action to be taken and an object describing the recipient of the action. The tasks are the basic units of the task analysis.

Estimate the Workload Required for Each Task

Workload is defined in this research as the total attentional demand placed on the operators as they perform the mission tasks. This research methodology recognized three different components of attention: cognitive, psychomotor, and sensory. Cognitive workload refers to the level of information processing required of the operators; psychomotor workload refers to the complexity of the operators' behavioral responses; sensory workload refers to the complexity of the visual, auditory, and kinesthetic stimuli to which an operator must attend. Short verbal descriptors for each of the workload components were written for each task. The descriptors were then compared to verbal anchors contained in 7-point rating scales designed to measure workload for each of the five workload components.

Estimate the Time Required to Perform Each Task

To develop a timeline for the OH-58D mission, the analyst and an aviator with over 500 hours experience as an OH-58D pilot estimated the time required to perform each task. Subsequently, a second experienced OH-58D pilot reviewed the time estimates for accuracy.

Allocate the Tasks and Functions

Using the aircraft checklist, operator's manual, flight training guides, and input from three subject matter experts, the analyst assigned each task to the pilot, copilot, or both crewmembers. In general, the pilot was assigned flight tasks, the copilot was assigned support tasks, and both crewmembers were assigned target acquisition and engagement tasks.

Develop the Workload Prediction Model

The mission/task/workload analysis used a top-down approach to identify the tasks that must be performed to accomplish the objectives of the OH-58D mission. That is, the mission was progressively decomposed into phases, segments, functions, and tasks. The analyst then estimated the time required to perform and the workload for each task. A bottom-up approach was used to develop the OH-58D workload prediction model. The approach started with the basic elements produced by the analysis (i.e., tasks) and successively composed the mission functions and segments.

The TAWL Operator Simulation System (TOSS) (see Hamilton, Bierbaum, & Fulford, 1991) was utilized to implement the OH-58D workload model. Function and segment decision rules were developed and entered into the TOSS program with the task data derived from the task analysis. A decision rule comprises the information necessary to schedule a task or function in the mission (e.g., start time and duration). The function decision rules combine the tasks into functions and the segment decision rules combine the functions into segments. The function and segment decision rules provided the information necessary to reconstruct the mission by simulating the behavior of each crewmember at each point on the mission timeline.

Future Research Requirements

The current OH-58D workload model has been completely developed according to the ARIARDA tasking requirements. The model is available for ARIARDA to use in evaluating proposed OH-58 design or mission modifications.

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HUMAN FACTORS DESIGN FOR
MAINTENANCE OF ARMY AVIATION SYSTEMS

Dr. John W. Ruffner, Project Director

Background

Even though there have been advances in the quality of maintenance training programs and job performance aids in recent years, Army aviation maintenance capabilities have not kept pace with the requirements. Army aviation systems have continued to increase in sophistication and complexity with little or no accompanying increase in maintainer skill levels and capabilities. Increased system complexity has resulted in increases in both the amount and complexity of maintenance requirements, particularly in the area of fault diagnostics. For example, Baker (1990) found a growing consensus among Army managers that there are not enough qualified soldiers to maintain the increasingly sophisticated aviation systems.

Several manpower and personnel factors have contributed to the disparity between aviation maintenance requirements and maintenance capabilities. First, it has become increasingly difficult for maintainers to achieve the skill levels required to maintain modern Army aviation systems during their first term of enlistment (Bond, 1987). Second, attrition among Army aviation maintainers has been high. Fewer than 40% of those trained in an aviation maintenance military occupational specialty (MOS) have reenlisted in the Army following their first 4-year term (U.S. Total Army Personnel Command, 1989). Attrition after the first enlistment term has produced a lack of both skilled maintainers and supervisors who are available for training the maintainers during their first term.

Third, the problem is likely to worsen. Over the next few years, a steady decline is projected in the traditional military target recruitment group of 18- to 21-year-old males in the U.S. population. The Army will have to compete with the other military services and with the civilian sector to attract the most capable individuals from the reduced recruitment pool (Dierker, Brandt, & Jerrigan, 1987). To attain the required maintainer manpower levels, the Army will have to recruit a larger percentage of individuals who traditionally have had lower maintenance-related aptitude levels than at present. Consequently, the average maintenance-related aptitude level of recruits is expected to decrease, thus increasing the training burden.

The discrepancy between maintenance requirements and maintainer capabilities is especially critical given the high costs of maintenance. Each year, approximately 25 - 30% of the annual budget for the Department of Defense has been expended for maintenance of military systems. The total maintenance costs for a piece of equipment throughout its life-cycle has often exceeded its acquisition costs (Christensen & Howard, 1981). Maintenance costs have often accounted for the highest percentage of an aviation system's total life-cycle costs.

In response to these problems, the Army initiated the Manpower and Personnel Integration (MANPRINT) program during the mid-1980s to ameliorate the manpower, personnel, training, human factors, health hazard, and safety problems associated with fielding complex systems. The primary objective of the MANPRINT program is to influence the design of military systems as early as possible so they can be operated and maintained by soldiers who possess the aptitudes, knowledge, and skills that the Army predicts will be available when the systems are fielded (Department of the Army, 1990).

In support of the MANPRINT program, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) developed a set of MANPRINT tools to enable system designers to predict the manpower, personnel, and training requirements for a proposed design (Booher & Hewitt, 1990). Once estimated, the requirements are compared with the system operation and maintenance performance requirements and with the predicted numbers, skill levels, and training of operators and maintainers. The tools are designed to enable designers to simulate the effect of different combinations of manpower, personnel, and training (MPT) variables on overall system performance and to provide a basis for evaluating MPT tradeoffs.

Although the MANPRINT tools are useful for evaluating the effects of MPT variables on system maintenance, they have two major shortcomings with respect to equipment design. First, the tools do not assess the effects of equipment design (human factors) variables on the maintainability of a proposed system. The user is required to supply estimated repair times for each component before running the simulation. The times are estimated as deviations from baseline levels for similar components in comparison systems. Thus, the validity of the times and the accuracy of the simulation depend on the similarity of the comparison systems to the proposed system. Second, although the tools are designed to work together to estimate the impact and interactions of MPT constraints and requirements, they do not

allow the user to evaluate the effects of equipment design variables on MPT requirements or of tradeoffs between MPT variables and equipment design variables.

Need

The literature suggests that equipment design is a major contributor to aviation system maintenance effectiveness. Current Department of the Army policy requires that maintainability be designed into systems and equipment rather than introduced through postdesign modifications suggested by test results, field complaints, or product improvement initiatives (Department of the Army, 1987). Therefore, there is a need (a) to understand the effects of equipment design variables on aviation system maintenance and their interactions with MPT variables and (b) to develop tools for estimating the combined effects of MPT and human factors (HF) variables on maintainer performance.

In December 1987, the Army Research Institute Aviation Research and Development Activity (ARIARDA) directed that Anacapa Sciences initiate research to address human performance problems in the area of Army aviation maintenance. During the first project conducted in this research area, Ruffner (1990) reviewed the literature on Army aviation maintenance, maintainability design, and several HF tools that were judged to be potentially useful for improving the maintainability design of Army aviation systems. He concluded that computer simulation models of maintainer performance have the highest utility for improving maintainability design and that a need exists to develop a comprehensive, integrated tool for predicting the maintainability of a proposed aviation system. Ideally, this tool should allow the user to predict the effects of a proposed system's design features on its maintainability as well as on its MPT requirements.

Research Objective

Before developing a comprehensive, integrated, prediction tool, a better understanding was required of the problems that exist in the maintenance of Army aviation systems. Therefore, this research project was designed (a) to develop a procedure for identifying problem areas in Army aviation maintenance and (b) to determine if the problem areas might be attributed to MPT or HF deficiencies. The research was limited to the two newest helicopters in the Army inventory, the UH-60A and the AH-64A.

Research Approach

The research approach was divided into two overlapping phases. During the first phase, fact-finding visits were scheduled to the U.S. Army Aviation Logistics School (USAALS), Fort Eustis, Virginia, and to field maintenance units at Fort Campbell, Kentucky, and Fort Hood, Texas. The purposes of the visits were to receive an orientation to maintainer training and to identify maintenance training and field maintenance problems and issues.

During the second phase, analyses were planned for historical maintenance data contained in the U.S. Army Aviation Systems Command (AVSCOM) Unscheduled Maintenance Sample Data Collection (UMSDC) data base. The purposes of the analyses were to identify the types of data available and to assess their utility for identifying Army aviation maintenance problems attributable to MPT or equipment design deficiencies.

Work Completed

Fact-Finding Visits

The visit to the USAALS was conducted in November, 1989. AH-64A and UH-60A instructors and subject matter experts (SMEs) indicated that the factors having the greatest impact on institutional maintenance training are insufficient training time and antiquated training equipment.

The visits to AH-64A and UH-60A maintenance units at Fort Campbell were conducted during April and May, 1990; the visit to the AH-64A maintenance units at Fort Hood was conducted in July 1990. SMEs at these locations indicated that the following factors have the greatest impact on field maintenance performance:

- excessively high equipment failure rates,
- insufficient personnel,
- excessive extra duties,
- a lack of institutional training in critical skills (e.g., troubleshooting),
- a lack of senior noncommissioned officers to support supervised on-the-job-training, and
- inaccessibility of high failure rate components.

Maintenance Data Base Analyses

Historical maintenance data were obtained for the AH-64A and UH-60A for the period 1 January 1987 to 31 December 1989, using standard AVSCOM statistical programs and reports. This period was chosen to provide relatively recent maintenance data and to minimize the influence of short-term problems (e.g., storm damage). At the end of the previous contract year, data summaries were completed for the AH-64A.

After examining all the variables available in the UMSDC data base, three variables proved most useful for identifying potential problem tasks: maintenance events, man-hours used, and maintainer MOS. A maintenance task was judged to be a potential problem task if it met at least one of three criteria:

- it occurred frequently, as indicated by a large number of maintenance events;

- it accounted for a large number of man-hours; or

- it required one or more MOSs that were difficult to recruit, expensive to train, or in short supply.

Potential AH-64A problem tasks were identified that accounted for a high number of maintenance events and man-hours. For each task, data were obtained on the MOSs that performed the task and the average task performance times for personnel in each MOS. Although the UMSDC data base provided information useful for identifying the MOSs, it did not provide recruiting, training, and supply data.

The analysis showed that the highest number of potential problem tasks were in the avionics, airframe, rotor, drive, electrical, and target acquisition and designation systems. Across all the components, the most frequently occurring types of potential problem tasks were repair and remove/replace. MOS 67R (crew chief, mechanic) was the MOS that performed the highest percentage of potential problem tasks, followed by MOS 35K (avionics mechanic) and MOS 68J (fire control repairer). The data for the potential problem tasks were organized into a separate data base that can be used during follow-on analyses.

Conclusions

The results of the fact-finding visits suggest that there are maintenance problems for the AH-64A and UH-60A that are attributable to MPT or HF deficiencies. The results of the UMSDC data base analyses suggest that it is useful for

identifying potential problem tasks. Data are provided that can be used to prioritize the tasks according to the criteria of interest and to select tasks for follow-on analyses.

However, the data base does not contain sufficient information to determine if the potential problem tasks are due to MPT or HF deficiencies, as opposed to reliability, supply, or administrative deficiencies. Determining the probable causes will require additional research, such as a detailed task analysis or survey of maintenance SMEs.

During the current contract year, a report (Ruffner, 1991) was prepared for ARIARDA that describes the results of the AH-64A data analysis.

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EVALUATION OF HARDMAN III TOOLS

Dr. D. Michael McAnulty, Project Director

Background

The Army Research Institute (ARI) has developed a set of six interrelated, personal computer (PC) based tools that can be used to analyze the manpower, personnel, and training requirements of developmental systems. The hardware versus manpower analysis tools (called HARDMAN III) can be used by combat developers in three ways. First, the system performance and reliability, availability, and maintainability (RAM) requirements can be described using the the System Performance and RAM Criteria (SPARC) tool. Second, three tools are available to combat developers for estimating the manpower constraints (M-CON), personnel constraints (P-CON), and training constraints (T-CON) that affect the system design. Third, two tools are available to evaluate the manpower and personnel implications of proposed system designs using the manpower-based system evaluation (MAN-SEVAL) and personnel-based system evaluation (PER-SEVAL) tools, respectively.

The first four tools are designed for use during the concept exploration phase of system development; the last two tools are designed for use during the demonstration and validation or proof-of-principle phases of development. The tools provide generic simulation routines and libraries of information about current systems, current military occupational specialty (MOS) duties and distributions, soldier aptitudes and performance data, and predicted personnel availability. The user can employ the tools to analyze system requirements and the implications of proposed system designs.

Need

The usefulness of the HARDMAN III tools has been demonstrated by ARI personnel who evaluated modifications to two existing weapon systems. However, ARI needs to demonstrate the usability of the tools by personnel who were not involved in their development and to demonstrate the utility of the tools for developing models that do not have predecessor systems in the HARDMAN III library. ARI also needs to determine whether the HARDMAN III tools or other, related computer programs are useful in evaluating unit designs.

Research Approach

Two projects were designed to meet the research needs. In the first project, Anacapa Sciences personnel, under contract to the Army Research Institute Aviation Research and Development Activity at Fort Rucker, Alabama, will first be given familiarization training on the HARDMAN III tools. Then, they will collaborate with personnel from the Directorate of Combat Developments (DCD) at Fort Rucker (a) to identify a current system-development problem that does not have a predecessor system in the HARDMAN III library and (b) to use the HARDMAN III tools to evaluate design alternatives. The Anacapa personnel will document any problems encountered in using the tools and will make recommendations for modifications.

In the second project, Anacapa personnel will review current computer programs that could potentially be used to address unit design problems and will develop a concept for employing them.

Work Completed

Develop and Evaluate a HARDMAN III Model

Beginning in July 1991, Anacapa personnel received training on using the HARDMAN III tools and installed the programs on PCs at Fort Rucker. In October 1991, ARI, DCD, and Anacapa representatives decided to use the HARDMAN III tools to evaluate alternative design concepts for forward arming and refueling point (FARP) operations. Recent experience by U.S. Army aviation units indicated there is an operational need to rearm and refuel at a FARP within 15 minutes of landing. With the currently available equipment, personnel, and procedures, FARP operations may take as long as 60 minutes to complete. The project was planned to provide a user demonstration of the HARDMAN III tools for ARI and quantitative information about the FARP concepts for DCD.

Subsequently, Anacapa personnel reviewed FARP manuals, videotapes of FARP operations, and the HARDMAN III manuals and then developed a preliminary task analysis of FARP operations for the AH-64 Apache helicopter. The preliminary task analysis was entered into the SPARC and MAN-SEVAL tools. Interviews were conducted with representatives of an attack helicopter battalion FARP platoon to determine the overall accuracy of the task analysis. Questionnaires were developed and delivered to the same soldiers to obtain more detailed

information about the time required to perform each task and the workload on the FARP personnel.

Develop a Unit Design Evaluation Concept

In the second project, Anacapa personnel have collected and reviewed information about several computer-based programs that can potentially be used to evaluate the design of Army units at the company and battalion levels. In addition to the HARDMAN III tools, the Anacapa researchers have obtained and exercised the Systematic Organizational Design (SORD) and Task Analysis/Workload (TAWL) Operator Simulation System (TOSS) software to compare the relevance of their output and the modifications that would be required to evaluate unit designs. The review indicates that no one program provides a satisfactory evaluation of unit designs, but that each of the programs reviewed can be used to evaluate portions of the unit.

Work Projected

Because this research area was initiated near the end of the contract year, work on the two HARDMAN III projects has been extended. In the first project, Anacapa personnel plan to collect detailed information about FARP operations, to refine the preliminary FARP model, and to develop and compare alternative FARP concepts using the HARDMAN III tools. In the second project, Anacapa personnel will formalize and deliver the unit design evaluation concept to ARI.

DEVELOPMENT AND VALIDATION OF THE NEW
FLIGHT APTITUDE SELECTION TEST (NFAST)

Dr. D. Michael McAnulty, Project Director

Background

The Army's original pilot selection battery, the Flight Aptitude Selection Test (FAST), was developed in response to the unacceptably high attrition rates in the Army flight training program during the 1950s. The FAST comprised two overlapping batteries, one for commissioned officer (CO) applicants and one for enlisted and civilian applicants to the Warrant Officer Candidate (WOC) program (Kaplan, 1965). The FAST, implemented in 1966, resulted in a substantial reduction in the flight training attrition rates.

In 1975, the FAST was revised to produce a single battery with fewer, shorter, and more reliably scored subtests. Eastman and McMullen (1978) selected 7 of the 12 FAST subtests for retention in the revised FAST (RFAST). They also eliminated subtest items that had poor psychometric characteristics (e.g., too easy or hard, low variability). The RFAST, implemented in 1980, was approximately one-half the length of the original FAST.

Subsequent research, however, indicated the need to develop a new FAST (NFAST) battery. Although Lockwood and Shipley (1984) found that the RFAST score and performance in initial entry rotary wing (IERW) training were significantly correlated, they concluded that the low percentage of variance accounted for by the RFAST indicates it has limited utility in predicting IERW performance. Oosterhof and Dohme (1984) identified several problems with the RFAST, including biased items, poor graphics quality, and the lack of an alternate form for retesting. Oosterhof and Dohme developed an alternate FAST to remedy the problems they had identified, but they did not develop any new tests for the selection battery.

As the first step in developing the NFAST battery, IERW instructor pilots (IPs) were asked to judge the type and importance of the abilities that are required to perform critical IERW tasks. Analyses of the task-ability ratings indicated that 24 abilities in the psychomotor, perceptual, language, and cognitive domains were required for successful performance in IERW. Abilities were selected for test development on the basis of their rated importance, amenability to paper-and-pencil measurement, and probability

of reliable measurement (McAnulty, Jones, Cohen, & Lockwood, 1984).

In the second step, nine new tests were developed and administered to 290 subjects as an experimental NFAST battery. Eight tests were each designed to measure a unique ability and one test was designed to measure a complex of abilities required for the successful completion of IERW training. The battery also included four standardized tests for comparison with the new tests. The results indicated that the complex ability test and six of the unique ability tests assessed reliable individual differences in the abilities of interest (McAnulty, Cross, & Jones, 1986). The remaining two unique ability tests had undesirable statistical characteristics or provided only redundant information.

Need

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has a continuing requirement to evaluate and improve the tests that are used to select applicants for the Army IERW training program. As indicated in the Background section, an NFAST battery is needed to improve the reliability and validity of the IERW selection process and to provide an equivalent form to be used for retesting IERW applicants.

Research Objective

The general objective of this research area is to develop a more effective battery of IERW selection tests. To accomplish this objective, the following research and development tasks must be performed:

- develop two alternate forms of the NFAST battery;

- conduct preoperational research to validate and equate the alternate forms of the NFAST battery; and

- produce and pretest the operational versions of the NFAST battery, including all required ancillary materials.

Research Approach

This research is part of the ongoing ARIARDA program in aviator selection and classification. The current aviator selection research is divided into two projects. The first project (NFAST Validation) is a predictive validity

investigation. The results of the experimental battery analyses will be used to develop two alternate forms of an NFAST validation battery. The preoperational validation research will be conducted (a) to determine the relationship between the NFAST tests, other predictor data, and performance in IERW training and (b) to test the equivalence of the alternate forms of the battery. During this project, measures of IERW performance will be identified and collected as flight training criteria.

The second project (Operational NFAST Development) is the development of the operational NFAST battery. The results of the validation analyses will be used to produce two alternate forms of the NFAST. In addition, all ancillary materials (administration manual, scoring manual, and information pamphlet) will be prepared for operational use. The operational battery and ancillary materials will be pretested on a sample of current IERW students. The pretest results will be used to make any final modifications to the tests and ancillary materials before they are submitted to ARIARDA.

Work Completed

Preoperational NFAST Validation

The validation battery development, data collection, and analysis activities on the NFAST Validation project have been completed. The results of the experimental battery research were used to develop two alternate forms of the NFAST validation battery. Each form consists of modified versions of the complex test and the six unique ability tests that had acceptable psychometric characteristics. In general, the validation battery tests are approximately two-thirds the length of the experimental battery tests. Finally, a knowledge test of helicopter operations and aerodynamic principles was adapted from the RFAST battery for inclusion in the validation battery. The items on the knowledge test are identical on both forms. Each form of the validation battery requires approximately 4 hours to administer.

Between March and October 1987, the alternate forms of the NFAST battery were administered to approximately 97% of the CO and WOC flight students during their first week of IERW training. When the test administration segment was completed, usable test data had been collected from 377 CO and 341 WOC students. IERW performance data were collected for these students until they either graduated or were eliminated from training.

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Test results. Analyses of the test data indicate that the flight student performance on the validation battery, excluding the helicopter knowledge test, is similar to the general population performance on the experimental battery. The average difficulty levels are near .50 despite the more restrictive time limits that were imposed on the validation tests, and the variances indicate that substantial individual differences in ability are being measured by the tests. The internal consistency estimates of reliability are also within an acceptable range. Performance on the two forms of the battery is very similar except for one of the unique ability tests. Test performance by the CO and WOC students is also quite similar, although the CO students scored significantly higher (p <.01) on four of the tests.

The results also indicate that the helicopter knowledge test is not difficult and that there is limited variability in the scores. WOC students scored significantly higher on the test than the CO students. However, there was no significant difference in performance by either student group on the two forms of the test. Because the two forms are identical, this result indicates there was no systematic sampling bias in terms of aviation-related knowledge in assigning students to the alternate forms of the NFAST battery.

Training results. Three types of IERW performance measures were collected about the students who participated in the NFAST validation: administrative changes (elimination and training setback data), flight hour data (number of flight hours required to complete each phase of training), and IERW training grades (academic and flight). The primary performance criterion was the Overall Average Grade (OAG), which is a weighted composite of the academic and flight grades. IERW performance data collection was completed in January 1989. Of the 718 students in the data base, 696 either completed IERW or were eliminated from training for flight or academic deficiencies; the remaining students were eliminated for nondeficiency reasons or were transferred for training under a different syllabus. The validation analyses were conducted using the 696 students who graduated or were eliminated for deficiency reasons.

Validation results. The results of the validation data analyses indicate that the alternate forms are approximately equal in predictive validity and that a subset of the tests in the battery will significantly improve the IERW selection process. Across all subgroups (e.g. forms, ranks, training track, education levels), three of the tests (the complex

Flight Planning test, the Chart Use test, and the Helicopter Knowledge test) consistently had high regression coefficients (R of approximately .50) on the OAG and other criteria. Cross validation analyses indicated that the regression equations were stable and are likely to generalize to the applicant population. Utility analyses demonstrated that fewer eliminations and deficiency setbacks will occur using the three NFAST tests. When the NFAST and RFAST tests were used in combined regressions, the Cyclic Orientation test also entered the equations.

During the current contract year, the draft validation report that documented the preoperational validation method and results was revised according to comments received from the ARIARDA peer review. The revisions included a section reporting the results of the operational battery pretest. The final report was submitted to ARIARDA in July of the current contract year (McAnulty, 1991c).

Operational NFAST Development

The results of the validation research were used to modify the validation battery for operational use. The modifications included shortening the test length, changing items with unsatisfactory characteristics, revising the test instructions, and improving the graphics and format of the tests. In addition, the Cyclic Orientation test was selected from the RFAST for retention in the operational NFAST battery. Finally, a test administration manual, a new answer sheet, a scoring manual, and an information pamphlet were developed for the operational NFAST.

Between October 1989 and June 1990, the 2-hour operational battery was pretested on a sample of 217 students waiting to begin IERW training. The results indicate that the modifications generally had their intended effect without adversely affecting the psychometric characteristics of the tests. One item on Chart Use test Form E was identified that required further revision; changes to the test chart graphics had resulted in two answers being equally correct. In addition, the pretest data were used to evaluate the effects of standardizing the test scores and correcting the scores for guessing. These data were used to develop the NFAST scoring manual.

The results of the operational pretest were included in the final report on the validation research. The alternate forms of the NFAST and the administration manual (McAnulty, 1990a, 1990b) were submitted to ARIARDA for review during the

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last contract year. The scoring manual and information pamphlet (McAnulty, 1991a, 1991b) were developed and submitted to ARI-ARIA in August and September, respectively.

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OH-58D WARRIOR CREW REQUIREMENTS

Dr. John W. Ruffner, Project Director

Background

Historically, the OH-58 aircraft has been employed in the unarmed aerial observation role with one rated pilot accompanied by an officer observer or an enlisted aerial observer (EAO). In January 1990, the Secretary of the Army directed that the role of the OH-58D helicopter be expanded to include armed reconnaissance, light attack, and multipurpose missions. To achieve this, the OH-58D was modified to carry HELLFIRE and STINGER missiles, 2.75 in. rockets, a 2,000 pound cargo hook for external sling loads, and external seats for troop transport. Thus equipped, the helicopter is known as the OH-58D Warrior, or the Multi-Purpose Light Helicopter, and can be used for rapid deployment to worldwide contingency operations.

An important issue that accompanied the modification was whether the OH-58D Warrior should be fielded with an authorized crew of two aviators or with the original Table of Organization and Equipment manning of one rated pilot plus an EAO (MOS 93B). In July 1990, the Training and Doctrine Command Systems Manager for the OH-58D requested that ARIARDA conduct research to investigate the potential benefits of adding a second pilot to the authorized OH-58D Warrior crew. ARIARDA developed a research plan and requested that Anacapa Sciences provide research support in August 1990.

General Research Objective

The general objective of this research is to provide the Army with an analysis of crew performance for the OH-58D Warrior with either a dual pilot or a pilot-EAO crew. The research addresses flight safety, mission flexibility, combat effectiveness, and crew endurance under conditions of stress and fatigue, with emphasis on crew performance with night vision goggles. Specific research objectives are identified for each Anacapa Sciences task under the research approach.

Research Approach

Six research tasks were identified in the ARIARDA research plan:

- conduct a literature review,

- perform an analysis of OH-58 accidents,

- develop and conduct structured interviews with OH-58D pilots and EAOs,

- compare Multitrack Test Battery data from EAOs and aviator candidates,

- perform a tactical mission simulation in the Army's Aviation Networked Simulator (AIRNET) facility, and

- perform an in-flight evaluation of OH-58D missions with dual pilot and pilot-EAO crews.

Anacapa Sciences personnel were directed to provide technical assistance on the first task and were given primary responsibility for performing the second, third, and fifth tasks.

Work Completed

Literature Review

The objective of this task was to assist in reviewing the literature relevant to the OH-58D crew mix question. This task had two specific objectives: (a) to identify instances where the on-board presence of a second aviator potentially would have avoided or minimized a mishap and (b) to identify specific deficiencies attributable to having a nonrated crewmember occupying the left seat. To accomplish these objectives, Anacapa Sciences personnel reviewed current POIs, flight training guides, and student handouts for the courses that are relevant to the OH-58D crew requirements issue. The following documents were reviewed:

- Aeroscout Observer Course POI, Course Number 600-93B10 (42);

- Aeroscout Observer Course Student Handout;

- OH-58 Enlisted Aeroscout Observer Course Flight Training Guide, Course Number 600-ASI-ZI;

- OH-58D Aeroscout Aerial Observer Qualification POI Course Number 600-ASI-W5 (93B) 4C;

- OH-58D Field Artillery Aerial Observer Qualification POI, Course Number 250-F31 (4J); and

- OH-58 Aviator Qualification Course POI, Course Number 2C-SI IA/2C-152D (4A).

Information from the POIs on course duration, flight time, training device time, and specific subjects trained was extracted, summarized, and submitted to ARIARDA during the previous contract year.

OH-58 Accident Analysis

Anacapa Sciences personnel extracted summary data from the Army Safety Management Information System for all OH-58 Class A - E accidents involving crew error that occurred between October 1983 and July 1990. The cases were reviewed to find instances in which a lack of air sense, poor attitudes about crew coordination, or inadequate knowledge of emergency procedures contributed to the accident. These cases were selected because they may provide the basis for establishing the minimal qualifications for the second crewmember in the OH-58D Warrior.

In the initial review, the Class A - C accident cases were categorized into those involving single pilots, dual pilots, and pilots plus aerial observers (AOs). Cases were also identified that require a more detailed analysis of the entire accident folder located at the U.S. Army Safety Center (USASC). Each case was reviewed by at least two analysts who compared their reviews and resolved any differences.

Instructions for the detailed review of each accident folder were prepared, the relevant data to be extracted were determined, and a form was developed for recording the information. The information included the type of mission, flight environment, phase of flight, workload levels, stress/fatigue levels, experience levels for each crewmember, the errors that were committed, and their causes. The analysis also included an assessment of the actions required to assist the pilot flying to preclude or minimize the accident and of the specific skills and knowledge that were needed to provide the assistance.

Each accident report selected for detailed review was examined by at least two analysts, and their reviews were compared to resolve any differences. Finally, the data were analyzed and comparisons made for each crew combination to determine if there was evidence in the accident data to support a specific crew composition for the OH-58D Warrior aircraft. In addition, an analysis of the mishap summaries (Class A - E) was undertaken to look for specific evidence related to a lack of air sense, poor crew coordination attitudes, or knowledge of emergency procedures. During the current contract year, a working paper summarizing the research approach and findings was prepared and submitted to ARIARDA (Zeller, Thornton, & Ruffner, 1991).

Structured Interview

The objective of this task was to obtain the opinions of pilots and EAOs about factors affecting the most appropriate crew composition for the OH-58D Warrior, particularly those factors that affect aircrew coordination. Anacapa Sciences personnel began work on this task by identifying OH-58D Warrior crew composition issues that needed to be addressed during the interview. The primary sources of information included the following:

- a questionnaire developed by the Directorate of Combat Developments about the fighting capabilities of the OH-58D Warrior under different crew compositions;

- discussions of dual pilot versus pilot-EAO crew composition issues with OH-58D instructor pilots (IPs) from the Training System Manager (TSM) - Scout office of the Directorate of Evaluation and Standardization;

- a review of the literature on (a) OH-58D tasks, techniques, and tactical deployment procedures and (b) aircrew coordination issues; and

- specific aircrew coordination issues identified in the ARIARDA research plan.

Project personnel then developed a draft version of a structured interview form, which was reviewed by ARIARDA and a TSM-Scout IP and subsequently revised. The final version of the interview form consists of two parts. In Part I, the respondent is asked to provide background information about relevant OH-58D experience (e.g., recent assignments, flight experience). In Part II, the respondent is asked about (a) the knowledge, skill, and ability requirements of the OH-58D Warrior crew during reconnaissance, light attack, and multipurpose missions; (b) crew coordination requirements; and (c) crew endurance and fatigue. In the crew coordination requirements section, the respondent is asked about five specific crew coordination issues: mission understanding, information exchange, workload management, cross-monitoring, and team relationships/aircrew climate.

The research plan originally called for the project personnel to conduct interviews with OH-58D aviators and EAOs in two Forces Command (FORSCOM) units. However, data collection in FORSCOM units was indefinitely postponed because of the deployment of U.S. forces for Operation Desert Shield. Therefore, the interviews were restricted to aviators at Fort Rucker with experience flying the OH-58D. Interviews were conducted with four OH-58D aviators who were attending the Officer Advanced Course. The four aviators interviewed had recent experience flying the OH-58D Warrior

with Task Force 118 in the Persian Gulf. One warrant officer instructor pilot assigned to the Directorate of Evaluation and Standardization completed the questionnaire on an individual, self-administered basis. During the current contract year, a working paper summarizing the research approach and findings was prepared and submitted to ARIARDA (Ruffner, Thornton, & Waters, 1991).

AIRNET Simulation

The objective of this task was to examine the performance of alternative crew mixes in a tactical OH-58D Warrior simulation. To accomplish this objective, Anacapa researchers planned to develop and run tactical scenarios in the AIRNET simulator located at the U.S. Army Aviation Center. In the tactical scenarios, the OH-58D Warrior aircrews would engage a simulated opposing force.

Anacapa Sciences personnel began work on this task by reviewing documents describing the tactical employment of the OH-58D Warrior. Subsequently, they developed tactical scenarios based on the reconnaissance (cavalry) and light attack missions that could be run in the AIRNET facility. The researchers also made a preliminary coordination visit to the AIRNET facility to review vehicle placements for the two mission scenarios. However, the evaluation of the crew composition issue in the AIRNET facility was indefinitely postponed in August 1990 because of the deployment of U.S. forces for Operation Desert Shield. In August 1990, the researchers prepared and delivered a memorandum to ARIARDA to document the details of the tactical scenarios and to make recommendations about experimental procedures.

Results

Literature Review

OH-58D EAOs initially qualify for the 93B military occupational speciality by completing the OH-58A/C Aeroscout Observer Course. During this course, the students learn to navigate, perform communications tasks, conduct reconnaissance, and acquire basic flight skills. In addition, they receive instruction on general aviation subjects and OH-58A/C aircraft operations. The course lasts 14 weeks and 3 days with 67 hours of flight time, of which 9 hours are devoted to EAO primary flight training

EAOs receive additional training and qualify for the W5 speciality skill identifier by completing the OH-58D Aeroscout Observer Course, which lasts 7 weeks and 3 days. During this course, the students receive 28 hours of instruction using the Classroom Systems Trainer, 20 hours using the Cockpit Procedures Trainer, and 41 hours of actual flight time. Of the 41 flight hours, 19 consist of minimal instruction in flying the OH-58D under normal visual flight rules conditions and in performing emergency handling tasks. The majority of the remaining time is spent in familiarization training with the OH-58D communications and navigation systems, the Mast-mounted Sight System, and the Airborne Target Handover System.

EAOs receive only about one half of the flight training provided to OH-58D aviators, with about one fourth of the EAOs' flight training hours devoted to hands-on flying. After assignment to an operational unit, EAOs are required to fly a minimum of 70 hours in the left seat semiannually and to receive 2 hours of training in emergency handling tasks every 90 days. In summary, EAOs are minimally qualified to fly the OH-58D if the pilot becomes incapacitated and are not trained to fly an aircraft that is damaged or disabled.

OH-58 Accident Analysis

Anacapa researchers reviewed 657 OH-58 Class A - E accident cases involving crew error during the period of October 1983 to July 1990. Thirty-four Class A - C cases were identified that required a more detailed review. Complete data were available at the USASC for 30 of the 34 cases: 9 of the accidents were single pilot, 14 were dual pilot, and 7 were pilot-AO crews.

Overall, the evidence associated with crew composition, flight experience, workload, stress/fatigue levels, and the types of errors committed by the crews in the accident sample does not offer strong support for either the pilot-AO or the dual-pilot crew mix. The workload levels were generally higher for the dual-pilot crews, but this is probably because of the more demanding missions and flight environments (e.g., nap-of-the-earth flight with night vision goggles) flown by these crews. Because many of the cases involved obstacle strikes, the primary assistance that the pilot flying needed was help with obstacle clearance, which does not require any special knowledge or skills. A few single-pilot cases appeared to indicate a need for a second pilot. However, the apparent need for a second pilot was contradicted by similar

dual-pilot cases in which the second pilot failed to provide the assistance needed to avoid the accident.

The accident data do suggest that the lack of air sense, poor crew coordination, and inadequate knowledge of emergency procedures occurs more often in OH-58D mishaps than in OH-58A/C mishaps. This implies that the more complex OH-58D may require a more skillful crew, possibly including two fully qualified aviators. This is especially true for emergency procedures in which AOs receive little if any institutional training. The Anacapa researchers prepared a report (Ruffner, Thornton, & Waters, 1991) describing the procedures and results of this task.

Structured Interview

The total flight experience of the interviewed aviators ranged from 1,100 to 6,800 hours; flight experience in the OH-58D ranged from 450 to 1,200 hours. Three of the aviators' experience was limited to dual-pilot OH-58D crews; two of the aviators had experience flying with an EAO.

The aviators with dual-pilot-only experience strongly preferred the dual-pilot crew option over the pilot-EAO crew option. They believed that a second pilot brought a more highly developed air sense and tactical mission sense to the crew. Thus, they believed the second pilot improved the capabilities of the aircraft, increased crewmember endurance, increased mission effectiveness, enhanced mission safety, and increased the likelihood of recovering the aircraft when the pilot flying became disoriented or incapacitated.

Of the aircrew coordination issues addressed, the aviators with dual-pilot-only experience believed a second pilot was more likely to have a common understanding of mission requirements, to perform more effective premission planning, to announce decisions affecting the other crewmember's actions, to request assistance from the other crewmember when overloaded, and to cross monitor the other crewmember's performance. The aviators identified the most critical factors favoring a dual-pilot crew as (a) mission factors (e.g., workload, task priority, and time pressure), (b) the flight environment (e.g., flying with night vision goggles over water), (c) safety, (d) cost (i.e., the minimum amount of additional time required for an aviator to acquire proficiency in left-seat tasks), and (e) flexibility in crewing the aircraft.

The aviators with pilot-EAO experience were more favorable toward using a pilot-EAO crew if the EAO has the appropriate training and experience. Although acknowledging that there are some exceptions (e.g., NVG flight over water), their experience suggests that a pilot-EAO crew could perform the majority of the missions required of the OH-58D.

All aviators agreed that the right-seat pilot's attitude toward having a pilot or an EAO in the left seat was strongly affected by previous experience. One of the two aviators with pilot-EAO experience was in favor of having a dual pilot crew rather than a pilot-EAO crew for the OH-58D Warrior, assuming the pilots are rated and qualified in both seats.

Final Report

The Anacapa researchers prepared a report (Zeller, Thornton, & Ruffner, 1991) that describes the procedures and results of this task. The report also includes a copy of the structured interview form.

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DEVELOPMENT AND EVALUATION OF AN
AIRCREW COORDINATION TRAINING PROGRAM

Mr. Joseph L. Zeller and Ms. R. Coleen Thornton,
Project Directors

Background

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has previously identified several deficiencies in the Army's current training programs for aircrew coordination. For example, aircrew coordination was loosely defined, assessment procedures were unclear, and aircrew skills thought to be important for enhanced safety and mission performance were injected haphazardly into training programs at various levels of the Army. Therefore, there is a need to determine the essential aircrew coordination skills for Army rotary wing flying and to develop methods for assessing and improving these skills.

In support of the ARIARDA accident prevention research program, Anacapa Sciences conducted a systematic review of a large sample of accidents for which human error was known to be a causal factor (Thornton & Zeller, 1991). Using the U.S. Army Safety Center's (USASC) Army Safety Management Information System (ASMIS) accident data base, two analyses were conducted of all rotary wing accidents that occurred between October 1983 and June 1989. In the first analysis, the accident data was reviewed to determine if aircrew coordination was a possible causal factor. In the second and more detailed analysis, the types of aircrew coordination errors that contributed to accidents were identified and classified into error types.

In these analyses, aircrew coordination was defined as the interaction between crewmembers (communication) and actions (sequencing or timing) necessary for flight tasks to be performed efficiently, effectively, and safely. These analyses showed that accidents caused by aircrew coordination errors accounted for approximately 15% of all human error accidents and that the percentage increased during the 6-year period. Aircrew coordination errors were 1.5 times more prevalent in night accidents than day accidents and frequently involved the task of obstacle clearance. The crew coordination errors were classified into six common problem areas: directing assistance, announcing decisions, using positive communication techniques, assigning responsibilities, offering assistance, and sequencing actions.

Project Objectives

The overall objective of this research is to develop and evaluate an aircrew coordination training program designed to meet the requirements of the Army's rotary wing flight regime. Specifically, the research is designed to accomplish the following:

- determine the relationship between aircrew coordination and performance on mission tasks,

- develop measures of aircrew coordination and methods of evaluating performance on aircrew coordination, and

- develop recommendations for a prototype aircrew coordination training program.

Research Approach

The research approach for this project is divided into two phases. In Phase 1, preliminary research will be conducted to (a) identify aircrew coordination requirements for helicopter aircrews that fly in tactical environments, (b) identify aircrew coordination training deficiencies, (c) develop performance and evaluation measures, and (d) develop experimental techniques and procedures. Because little is known about rotary wing crew coordination, an observational rather than experimental approach will be used for the preliminary research. The observations will provide information necessary to develop hypotheses and techniques for subsequent experimentation.

In Phase 1, 20 UH-60 aircrews assigned to an aviation field unit will be observed conducting a standard tactical training mission in the UH-60 Flight Simulator (FS). The training scenario will be constructed to simulate missions for which the aviators normally train. The 2-hour scenario will comprise three segments: a resupply mission, an air assault mission, and an instrument flight mission. The segments of the scenario will vary in difficulty without exceeding the capabilities of the majority of the crews.

Each aircrew will receive a standard mission briefing and will be allowed 2 hours to conduct premission planning. After completing the premission planning, the aircrew will enter the UH60FS and begin its mission. The UH60FS will be equipped with four video cameras that will provide continuous views of each crewmember's face, the center console of the UH60FS, and the visual scene observed by both crewmembers. Video and audio recordings will be obtained for each aircrew

from the time the aircrew activates the communications systems until they leave the simulator.

Aircrew task performance will be measured relative to conventional flight standards and in terms of aircrew coordination. Measures of aircrew coordination will be developed to examine patterns of intercrew communication for effective and ineffective aircrews during the three mission segments.

During Phase 2, Anacapa Sciences researchers will work closely with the U.S. Army Aviation Center (USAAVNC) in developing new aircrew coordination training standards for inclusion in the various Aircrew Training Manuals (ATMs). The initial efforts will focus on the Commanders Guide (Training Circular [TC] 1-210) and the AH-64 Apache ATM (TC 1-214). As a participant of the USAAVNC aircrew coordination committee, Anacapa researchers will assist the USAAVNC proponent in developing and formatting the specific crew coordination requirements for each ATM task and validating the results.

Work Completed

Phase 1 of the research has been completed. The results of the accident data analyses were used to develop a representative tactical scenario that provided opportunities for crew coordination errors to affect performance. The scenario was developed with the assistance of instructor pilots from the 101st Airborne Aviation regiment. The tactical evaluation scenario was installed in the UH60FS and the performances of 20 aircrews were recorded while flying the tactical mission scenario. The audio portions of the videotapes were transcribed for the tactical and instrument mission segments. Analyses of communication and mission effectiveness were conducted to identify the nature of the relationship between communication patterns, type of mission, and mission performance measures.

Checklists were developed to summarize the performance of each aircrew during selected phases of the mission. The phases included threat encounters, stabilator failures, inadvertent entry into instrument meteorological conditions, and a nonprecision instrument approach. The checklists were used to analyze the videotapes and transcriptions to produce measures of mission effectiveness.

The pattern of crew communication served as the principal measure of aircrew coordination. Two analysts, working independently, decomposed the aircrew's verbal

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comments into individual message units and classified each message unit on three dimensions: topic (e.g., navigation, mission), category (e.g., inquiries, directives), and subcategory (e.g., system status input). Then the analysts compared the message unit classifications and reconciled all coding differences.

The results indicate there were substantial differences in performance and communication profiles between crewmembers and mission segments. In addition, there were significant relationships between the level of crew coordination and performance on the three types of mission tasks. Finally, the results indicate the need for aircrew coordination training for Army helicopter pilots, particularly for synchronizing the actions of the two pilots.

A Phase 1 technical report (Thornton, Kaempf, Zeller, & McAnulty, 1991) was prepared and submitted to ARIARDA for review in June 1991. The report documents the results of the communication and mission effectiveness analyses and makes recommendations for aircrew coordination training.

During Phase 2, Anacapa provided technical assistance to several USAAVNC elements involved in integrating crew coordination requirements into Army training manuals and instructional programs. Anacapa researchers reviewed drafts of the new TC 1-210 and TC 1-214 and suggested improvements, including a proposed crew coordination concept statement for the introduction section of the manuals. Anacapa researchers also assisted the U.S. Army Safety Center (USASC) and the Aviation Training Brigade (ATB) in developing a training videotape concerning crew coordination and night flight in the desert. Segments of actual flight footage were reviewed for inclusion in the film, and crew coordination concepts were inserted in the script of the premission planning briefing and flight.

Anacapa also provided technical assistance to the Directorate of Evaluation and Standardization (DES) in evaluating the draft TC 1-214 by assessing five aircrews made up of instructor pilots performing 25 different ATM tasks during a short attack helicopter scenario. The crews were first evaluated on the current ATM tasks to establish a baseline. Following two practice simulator periods using the revised task descriptions, the crews were evaluated again. Both evaluation periods, including the premission planning segments, were recorded on videotape. The videotapes were reviewed and each maneuver graded for all five crews. Comparisons between the initial and final evaluation periods were analyzed and a briefing describing the results obtained from the videotape reviews was conducted for DES. The

results indicate that the crew coordination requirements were feasible and that there was a noticeable improvement in coordination among the crews between the initial and final evaluations.

Finally, Anacapa provided technical assistance to the ATB in evaluating their efforts to integrate crew coordination into the AH-64 Instructor Pilot Course (IPC). Anacapa researchers taught the IPC instructor pilots about crew coordination, modified the daily gradeslips for the IPC to include crew coordination requirements for the selected ATM tasks, reviewed the on-board videotapes of selected training flights, and developed an end-of-course critique for the instructor pilots. The gradeslips, videotapes, and critiques were analyzed and a report (Zeller, in preparation) about the results was prepared and submitted to the ATB and DES for review. The results indicate that the crew coordination requirements contained in the 13 ATM tasks selected for the evaluation were valid. The results showed that the crew coordination requirements should be introduced as soon as the student is able to handle the additional workload. The results also indicated that the lack of academic classes on crew coordination to supplement the flight instruction may have hampered the students and IPs from fully understanding the training and evaluation concepts.

Recommendations

The findings of Phase 1 of this research indicate that crew communication can be used as an index of crew coordination. The findings also indicate there is a relationship between crew coordination and mission effectiveness, and ultimately flight safety, in Army rotary wing operations. Because of the observational nature of this research, the results should be verified through the development and evaluation of a prototype crew coordination program. Any extension of the present investigation should also include a night training scenario, preferably, using night vision devices to determine if different crew coordination requirements are associated with the night environment. In addition, future research should include other Army aircraft such as the AH-64 and CH-47 to determine if there are any unique crew coordination aspects associated with tandem seating, weapon system operations, or multicrewed aircraft.

The results of the technical assistance efforts indicate that most of the crew coordination requirements in the selected ATM tasks are valid. Furthermore, the results indicate that the crew coordination requirements should be

introduced into the course as early as possible after the
student is able to perform each ATM task. Finally, academic
classes should be revised to incorporate the new training
standards for crew coordination and the lessons learned from
these evaluations.

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EVALUATION OF THE AVIATOR NIGHT VISION IMAGING SYSTEM HEAD-UP DISPLAY (ANVIS-HUD)

Dr. John W. Ruffner, Project Director

Background

Current U.S. Army doctrine requires that helicopter pilots perform many night missions at terrain flight altitudes using night vision goggles (NVGs), a binocular night vision device that amplifies available light. Night terrain flight with NVGs, especially in the nap-of-the-earth (NOE) mode, is very demanding and fatiguing and often results in a high level of individual workload. During night NOE flight with NVGs, it is difficult and potentially unsafe for the pilot on the controls to divert his or her attention from the out-the-window external scene to obtain critical flight information from cockpit instruments (Department of the Army, 1988).

The most recent version of the NVGs, the Aviator Night Vision Imaging System (ANVIS), allows the pilot to view cockpit instruments by looking under or around the goggles. However, reading instruments that differ in illumination and optical distance from the NVG image of the external scene is time consuming and difficult. Therefore, a pilot often must rely on verbal information from the copilot about the aircraft status while maintaining attention outside the cockpit. This procedure requires a high level of cooperation and coordination by flight crews and may increase crew workload.

To address this problem, the U.S. Army is considering superimposing flight symbology (e.g., altitude and airspeed) on the image presented in one of the NVG intensifier tubes. This concept is similar to the head-up display (HUD) in which symbolic information is projected on a combining glass or on the aircraft windscreen, allowing the pilot to view both the symbology and the external scene simultaneously. Adding symbology to the ANVIS results in a display system in which imagery and symbology are integrated and projected on a surface mounted to the pilot's helmet. The combined system is known as the ANVIS-HUD.

Although the ANVIS-HUD system offers several potential benefits, there is a concern that it may inappropriately distract the pilot's attention from the tasks of obstacle detection, recognition, and avoidance and may interfere with NVG visual scanning patterns (Larish & Wickens, 1991). Furthermore, the ANVIS-HUD may contribute to errors in

pilots' judgments of distance, altitude, and closure rates and to the tendency to become spatially disoriented (e.g., Roscoe, 1987).

Need

The Army plans to acquire the ANVIS-HUD kit for the UH-60A/L, OH-58A/C, UN-1V, AH-1F, and CH-47D and is currently engaged in an accelerated system test, acquisition, and fielding program. At a fully funded level, up to 600 units will be acquired over the next 5 years, representing a potential investment of approximately $150 million.

A limited amount of data are available about aviator performance with the helmet-mounted display used on the AH 64A Apache and with prototype NVG-HUD systems (e.g., Hale & Piccione, 1990; U.S. Marine Helicopter Squadron One, 1989). However, these data are largely anecdotal and judgmental and offer little insight into the expected performance benefits or shortcomings of the ANVIS-HUD. Therefore, the Army Research Institute Aviation Research and Development Activity (ARIARDA) requested that Anacapa Sciences initiate a program of research to investigate potential safety problems with the ANVIS-HUD.

Objectives

This research has five objectives: (a) to determine if adding HUD symbology to the ANVIS will degrade aviators' abilities to detect critical events in the external scene, (b) to determine if adding HUD symbology will degrade an aviator's ability to judge distance, altitude, and closure rates, (c) to determine if adding symbology will contribute to the tendency to become spatially disoriented, (d) to identify relevant individual differences in aviators' abilities to use the ANVIS-HUD effectively, and (e) to identify areas for follow-on research.

Research Approach

The approach adopted to meet the research objectives consists of two overlapping phases. During Phase I, the literature on NVGs, HUDs, and helmet-mounted displays (HMDs) will be reviewed to identify issues that warrant investigation. During Phase II, a series of experiments will be conducted to investigate the effects of relevant variables identified during the literature review. The experiments

will focus on aviators' abilities to detect expected and
unexpected symbology and external scene events. The
experiments in Phase II will be carried out using a
laboratory simulation of the ANVIS-HUD and ARIARDA's Training
Research Simulator (TRS). The TRS consists of a UH-1 motion
simulator equipped with a video system that presents imagery
to both front windows and the right-seat side window.

Work Completed

Phase I

    Anacapa Sciences began work on the literature review in
February 1991. In addition to reviewing the literature, the
project director conducted a fact-finding visit to the 160th
Special Operations Aviation Regiment (SOAR) in Fort Campbell,
Kentucky, in April 1991. The SOAR had recently completed an
informal evaluation of one version of the ANVIS-HUD. The
160th SOAR found the ANVIS-HUD to be generally acceptable but
expressed several concerns about many of the ANVIS-HUD's
design features and potential safety problems.

    A draft report (Ruffner, Grubb, & Hamilton) summarizing
the results of the literature review was completed in
December 1991. The literature review produced the following
four general conclusions.

- The performance limitations imposed by night
  operations and by NVGs must be thoroughly understood
  before assessing the additional effects of adding a
  symbology to the ANVIS.

- Superimposing symbology on the ANVIS image may
  contribute to distance estimation errors,
  inappropriate diversion of attention, and spatial
  disorientation.

- The tendency to divide attention inappropriately
  between the external scene and symbology is likely to
  be strongest under conditions of high workload and for
  unexpected symbology or external scene events.

- The effects of individual differences in aviators'
  abilities to use NVGs, HUDs, and HMDS should be
  investigated.

    In addition, Anacapa Sciences personnel provided
technical advice during Phase I to Dynamics Research
Corporation, the project subcontractor, in investigating the

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feasibility of modifying the TRS hardware and software to superimpose symbology on the external visual scene (see the summary in this report entitled "Technical Assessment of Helmet-Mounted Display Symbology for the ANVIS Night Vision Goggles").

Phase II

Work on Phase II began in July 1991. Anacapa researchers constructed an experimental apparatus to simulate the ANVIS-HUD viewing conditions. The apparatus consists of a videotape and videodisc player for presenting video footage of flight segments, two monitors and reflecting mirrors for presenting the video footage separately to the aviator's left and right eyes, and a personal computer for overlaying symbology on the video image of one of the monitors and for controlling the experiment. An alternate configuration of the apparatus permits the use of a head-mounted eye tracker for recording aviator eye movements and scanning patterns using a single monitor. Videotape footage was obtained during NOE flights conducted in the Fort Rucker local flying area in October, 1991. Videodisc footage is available from videodiscs previously developed for ARIARDA by Anacapa Sciences for the Map Interpretation and Terrain Analysis project.

At the end of the contract year, the project personnel had completed constructing and testing the laboratory simulation apparatus. In addition, they had developed procedures for superimposing and controlling symbology on the visual scene and for recording performance measures. Three experiments using ARIARDA's laboratory simulation facility were planned. One experiment will examine the effects of practice with ANVIS-HUD symbology on aviators' scanning patterns and situational awareness. Two experiments will examine the effect of eye dominance on aviators' abilities to detect expected and unexpected symbology events and external scene events.

Future Research Requirements

The Phase I and Phase II efforts have identified critical research issues and provided an apparatus to conduct experiments to address the issues. ARIARDA should conduct the experiments planned for the laboratory simulation apparatus and the TRS, analyze the results of the experiments, and prepare a report summarizing the results.

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EVALUATION OF SPECIAL OPERATIONS AVIATION REGIMENT (SOAR) CONTRACTOR MISSION INSTRUCTORS

Mr. Carl R. Bierbaum, Project Director

Background

The Selection and Training (S&T) Detachment, 160th Special Operations Aviation Regiment (SOAR), Fort Campbell, Kentucky, conducts Basic Mission Qualification (BMQ) training for prospective special operations crewmembers. The BMQ training is an intensive, night vision goggle, low-level navigation course that includes an introduction to new aircraft systems. Traditionally, the S&T Detachment has utilized active duty aviators as military mission instructors (MMIs) for BMQ training. The active duty MMIs are fully qualified to conduct the requisite training, but the requirement to conduct the training in addition to their normal duties places an excessive burden on the MMIs and reduces the availability of trained aviators for assignment to operational missions. One potentially effective method for addressing these problems is to employ contractor mission instructors (CMIs) for BMQ training.

In September 1989, the Army Aviation Systems Command (AVSCOM) requested that ARIARDA evaluate the feasibility and effectiveness of employing CMIs. ARIARDA, in turn, tasked Anacapa Sciences to conduct the evaluation. The project was initiated in July 1990.

Research Objectives

There are two general objectives for this research project:

- evaluate the instructional training materials for possible upgrade and
- evaluate the training effectiveness of CMIs.

Research Approach

Anacapa researchers developed a research plan to address the research objectives for three of the aircraft systems (CH/MH-47, UH/MH-60, and AH/MH-6) trained by the S&T Detachment. First, the existing training program will be reviewed to gain an understanding of the BMQ training objectives and methods. Project personnel will examine the training program, note the types of instruction, and select

instructional material that can be upgraded. In addition, they will identify measures of training effectiveness that currently exist in the program and determine what additional measures should be developed.

Second, the class members for each of the three aircraft will be divided into two groups, one instructed by MMIs and the other by CMIs. Students will be divided into groups on the basis of their flight time in the assigned aircraft, total flight time, rank, age, highest qualification held, and night vision goggle experience.

Third, the effectiveness of the MMIs and CMIs will be evaluated in the academic and flight phases of training. Academic classes taught by CMIs and MMIs will be evaluated by an observer from the S&T Detachment. Academic examinations will be developed to compare student performance on subjects that are taught by CMIs and MMIs. Students will perform BMQ tasks on the Omega and the Cockpit Management System hot bench trainers. Subject matter experts will observe the performance and complete evaluation gradeslips. Student performance will also be evaluated for each segment of flight training. Finally, the students will assess the performance of their academic and flight instructors and will complete a self-appraisal of proficiency on selected flight tasks before and after the BMQ course.

Work Completed

Program Review

The Anacapa researchers reviewed the existing training program to gain a clear understanding of the training objectives and the methods currently being used to train prospective SOAR aviators. The material was then organized into reference binders and all test materials were updated.

A 118-item, 2-hour academic examination was developed to test the following subjects taught by the CMIs and MMIs:
- Shipboard Operations,
- Visual Flight Rules,
- Forward Arming and Refueling Point Operations,
- 160th Local Flying Area,
- CAM Reg 95-1/Waivers,
- Environmental Operations, and
- Mission Planning.

The examination contains multiple choice, multiple check, matching, fill-in-the-blank, and short answer items. In

addition, the following examinations were developed for the academics taught during the flight phase of training:

- Light Airborne Forward-Looking Infrared (FLIR) Systems (LAFS),
- Cockpit Management Systems (CMS-80),
- MH-6 Aircraft Systems, and
- MH-6 Aircraft Loading.

The operator's manual (-10) examinations for the CH-47, UH-60, and MH-6 were reviewed and updated.

Twenty gradeslips were developed for the flight and performance checks. In addition, seven student instruction handouts were developed for evaluating Basic Navigation, CMS-80, LAFS, Omega, All Weather Cockpit (AWC), and BMQ Mission Briefing. The handouts provided the background information necessary for the students to perform the specific operations to be evaluated.

Assessment forms were developed for students to complete after each academic class. Observer assessment forms were also developed to be completed by an independent observer for each academic class. Flight phase assessment forms were developed for students to complete after the flight phase was completed. In addition, a questionnaire was developed to collect background information about the BMQ students.

Data Collection

Data were collected from Classes 91-02, 91-03, and 91-04 of the BMQ course. During the academic phase, Class 91-02 was taught by CMIs, Class 91-03 was taught by MMIs, and Class 91-04 was taught by CMIs. Three MH-6, four CH-47, and three UH-60 students of Class 91-02 and four CH-47 and three UH-60 students in Class 91-03 were divided into CMI ($n = 9$) and MMI ($n = 8$) training groups during the flight phase. Class 91-04 and all the AH-6 students were evaluated only in the academic phase. In addition, 31 operational aviators took the academic examination as a baseline measure of performance.

Results

Direct evaluations (student and observer assessments) of the instructors indicated that both MMIs and CMIs provided a very good quality of instruction. The students rated the MMIs as equal to or slightly better than the CMIs in the academic phase. During the same phase, the independent observer consistently rated the CMIs as slightly better than the MMIs. The students consistently rated the CMIs as

slightly better than the MMIs during the flight phase of training. In both phases, the differences between the MMI and CMI assessments by the students and the observer were small, and in all cases the instructors were rated as providing good instruction or better.

Indirect evaluations of the instructors were made by assessing the performance of their products, the prospective special operations aviators. An analysis of the students' backgrounds indicated that the MMI- and CMI-trained students were sufficiently similar before the BMQ course began that comparisons of instructional effectiveness could be made by examining student performance. The MMIs and CMIs were equally effective in conducting academic training, as measured by the students' performance on the academic examination. Furthermore, both groups of students performed better than a baseline group of operational aviators on the academic examination.

During the flight phase of training, both the MMI and CMI students performed equally and satisfactorily on the Commander's Evaluation, the written examinations, the hot bench evaluations, and the flight phase putup evaluations. All the students received satisfactory ratings on the flight check evaluations, with the MMI students being rated slightly higher on one checkride and the CMI students being rated slightly to moderately higher on the other four check evaluations. Finally, the students' self-appraisals on 11 flight tasks indicated an increase in proficiency as a result of the BMQ course. The CMI students indicated a slightly larger increase in proficiency than the MMI students.

Overall, the research results indicate that the CMIs provided effective BMQ training that was similar in quality to the training produced by the MMIs. In addition, the CMIs provided a more consistent training program in terms of the number of instructor pilots (IPs) involved in the training (6 CMIs vs. 18 MMIs). Not only did the CMI students benefit from having the same IP throughout a flight segment, but the CMIs were able to benefit from their experience with one class and improve their instruction in subsequent classes. Finally, using CMIs limited the BMQ training workload for the operational unit IPs to serving only as check pilots. The research results indicate that employing CMIs would be an effective method for conducting the BMQ course, with a reduction in other problems associated with using MMIs (turnover, IP overload).

The commander of the 160th SOAR was given a final briefing on the project results in September 1991 and a report on the CMI program evaluation was prepared and

submitted to ARIARDA in October 1991 (Bierbaum, McAnulty, &
Cross, 1991).

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TRAINING EFFECTIVENESS ANALYSIS OF THE AH-1
FLIGHT AND WEAPONS SIMULATOR (FWS)
FOR UNIT TRAINING

Dr. ⁀. Michael McAnulty, Project Director

Background

This research area was initiated in response to two taskings from the Directorate of Training and Doctrine (DOTD) to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama. One tasking originated at the USAAVNC and the other originated at the Department of the Army (DA). The taskings have been discussed in detail previously (see Cross & Gainer, 1987; Kaempf, 1988). Therefore, only a brief review of the taskings is presented in this report.

USAAVNC Tasking

The Army Audit Agency (AAA) audited the Army's Synthetic Flight Training System twice, first in 1981 and again in 1984. The audit reports (AAA, 1982, 1985) stated that, although flight simulators had reduced training costs and improved training at the USAAVNC, the Army had not determined the effects of using flight simulators to train aviators in operational units. Both reports concluded that the Army had not adequately quantified the return on its investment in flight simulators procured for aviation unit training.

In response to the audits, the Commander of the USAAVNC tasked DOTD to initiate research to address the issues raised by the AAA. In 1985, the Director of DOTD formally tasked ARIARDA to plan and conduct the needed research. Subsequently, ARIARDA and Anacapa personnel initiated three research projects in the AH-1F Flight and Weapons Simulator (FWS): backward transfer and skill acquisition in the FWS, transfer of training in the FWS for emergency touchdown maneuvers (ETMs), and transfer of training in the FWS for gunnery skills. The first two projects have been completed (Kaempf & Blackwell, 1990; Kaempf, Cross & Blackwell, 1989); the third project was planned but was later subsumed under the work conducted for the DA tasking.

DA Tasking

In 1986, the issues concerning developing flight simulation training programs and fielding flight simulators were reviewed by the Office of the Deputy Chief of Staff for Operations (DCSOPS). Subsequently, the DCSOPS directed that training effectiveness analyses (TEAs) be conducted for each of the Army's flight simulator systems. The analyses were intended to serve as the basis for developing effective training strategies and programs. ARIARDA and Anacapa developed and submitted a research plan (U.S. Army Research Institute, 1986) that addressed the utilization of flight simulators in operational environments. In June 1987, the Commander of the Training and Doctrine Command (TRADOC) approved the TEA research plan and authorized ARIARDA to implement the research.

Gunnery Training Focus

Concurrent with the TEA tasking, the Department of Tactics and Simulation (DOTS; formerly the Department of Gunnery and Flight Systems) at the USAAVNC revised the helicopter gunnery training manual (FM 1-140). The revised manual, designated TC 1-140 (1988), specified the gunnery training requirements and performance standards for aviation units. Before issuing the revised manual, however, DOTS requested that ARIARDA incorporate into the TEAs an analysis of the proposed crew gunnery training programs. The objectives of the analysis are (a) to determine whether simulators can be used to train crew gunnery tasks effectively in aviation units and (b) to determine the resources required to support crew gunnery training programs.

In response to the DOTS request, the TEA program focused on the effectiveness of flight simulators for training gunnery tasks in attack helicopter aviation units. ARIARDA and Anacapa personnel planned and initiated three research projects for gunnery tasks: TEA of the FWS for Conducting Gunnery Training, TEA of the AH-64A Combat Mission Simulator (CMS) for Conducting Crew Gunnery Initial Qualification Training, and TEA of the CMS for Conducting Crew Gunnery Proficiency Sustainment Training. The FWS TEA is described under this research area; the CMS TEAs are described in the research area entitled "Training Effectiveness Analysis of the AH-64A Combat Mission Simulator."

Previous FWS Research

Previous research has concentrated on performing flight tasks and emergency procedures and on acquiring flight skills in the FWS; it has not directly evaluated the issue of skill sustainment or the forward transfer of sustainment training from the FWS to the AH-1. Kaempf, Cross, and Blackwell (1989) found that experienced AH-1 pilots required simulator-specific training to perform flight tasks in the FWS. The pilots attributed their performance difficulties primarily to the FWS visual system and handling qualities. Kaempf et al. also found that 36 of 40 flight skills could be acquired in the FWS, but that multiple training iterations were required to attain a minimum standard of performance. Finally, Kaempf and Blackwell (1990) investigated the effects of FWS training for five emergency maneuvers that were prohibited in the aircraft for safety reasons. They found that unit aviators, who initially exhibited uniformly poor performance on the maneuvers, were able to improve their skill in the FWS but required additional aircraft training to perform the maneuvers successfully.

Problem

The Army has made a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. Visual flight simulator systems have been developed and deployed to aviation units for the AH-1F, AH-64A, CH-47D, and UH-60 helicopters. The Army's primary objective for flight simulation is to provide training devices in which operational aviators can sustain their flight and tactical skills. However, little empirical data currently exist (a) to demonstrate that flight simulators effectively and efficiently provide this type of training and (b) to guide the Army in developing training programs that include an optimum mix of training conducted in both the aircraft and the flight simulator. Empirical data are needed to ensure that the Army receives the maximum return on its investment in flight simulators.

The FWS limitations found in previous evaluations indicate that forward transfer of training research is needed before the FWS is used extensively for training unit aviators. Because the previous efforts have addressed only the acquisition of flight and emergency procedure skills, research about the effectiveness of the FWS for sustainment and gunnery training is particularly important.

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Research Objectives

The primary objective of this research is to evaluate the effectiveness of the AH-1 FWS for sustaining crew gunnery proficiency in operational units. In addition, data are needed to develop unit training programs that provide an optimal mix of flight simulator and aircraft training and to determine the simulator and ammunition resources required to sustain aerial gunnery skills.

Research Approach

Fifty current AH-1F aviators in U.S. Army, Europe (USAREUR) aviation units will be assigned to one of three groups: one control and two experimental. Each aviator's proficiency on crew gunnery tasks will be evaluated during an initial live-fire gunnery exercise. Following the initial live-fire evaluation, the aviators will enter a 13-month gunnery training program. In addition to the normal unit training, the Experimental Group 1 aviators will receive gunnery training in the FWS every month and the Experimental Group 2 aviators will receive gunnery training in the FWS every 3 months. Aviators in both experimental groups will be restricted on the gunnery tasks they can practice in the aircraft. The Control Group aviators will receive the unit's normal training in the aircraft but will be restricted on gunnery practice in the FWS. The effectiveness of the FWS for sustaining gunnery skills will be tested by comparing the performance of the three groups during a final live-fire exercise.

Work Completed

In October 1988, USAREUR officials authorized ARIARDA to conduct the TEA of the FWS and tasked V Corps and VII Corps to provide resources to support the experiment. V Corps divided the tasking between two aviation units (n = 12 and 13); VII Corps provided 26 AH-1F aviators from one unit to participate in the research. Because of logistical and scheduling considerations, each of the aviation units entered the experiment as its training schedule permitted and proceeded independently of the other units.

An AH-1F Aviator Questionnaire was developed and administered to AH-1F aviators in USAREUR units. The questionnaire contains 44 items requesting information about personal history, flight experience, current duty assignment,

experience with AH-1F weapon systems, and opinions about flight and gunnery training. The objectives of the questionnaire were to describe (a) the aviators participating in the TEA and (b) the population of AH-1F aviators from which the participants were selected. Approximately 200 AH-1F aviators responded to the questionnaire, including the 51 TEA aviators.

Two other data collection instruments were developed for the TEA: the Diagnostic Gunnery Skills Test and the Postflight Debriefing Form. The Diagnostic Gunnery Skills Test comprised 32 items designed to test the aviators' knowledge of the AH-1F weapon systems and gunnery techniques. All aviators completed the test prior to their initial live-fire exercise. The Postflight Debriefing Form comprised 16 items that document the training that the aviators receive in the aircraft in conjunction with their training in the FWS. Gunnery and tactical tasks are emphasized on the form. All aviators were instructed to complete a debriefing form immediately after each flight in the aircraft.

The three participating units conducted their initial live-fire exercises in January, April, and May 1989, respectively. Following the initial live-fire exercises, Experimental Groups 1 and 2 began the TEA training program. The TEA training program was designed to sustain proficiency on specific gunnery tasks within the context of mission scenarios. During each FWS training session, the aviators planned and executed an attack mission prepared by Anacapa personnel and AH-1F standardization pilots. Nine attack missions were developed for the FWS training sessions. During each FWS training session, a data collector recorded several performance measures, including total engagement time, target effect, flight time in each crew station, and number of rounds expended.

In July 1989, the Chief of ARIARDA directed that Anacapa terminate work on the FWS TEA by 30 August because of a funding shortage. During the next 3 months, ARIARDA personnel continued the FWS training and data collection. Also during this period, one of the V Corps units withdrew from the research project. Anacapa personnel resumed work on the project in November 1989.

The remaining V Corps unit conducted their final live-fire exercise in February 1990. The VII Corps unit conducted its final live-fire exercise in August 1990, after being postponed from the scheduled April - May 1990 range dates. During the final exercise, each crew fired the VII Corps Crew Qualification Table (Table VIII). Table VIII comprises 10 engagements fired from seven firing positions. The crews

fired the 20 mm cannon five times, the 2.75 in. rockets four times, and the TOW missile once during the exercise. Four of the firing positions were single engagements and three of the positions were combined engagements. Data collectors recorded measures of target effect, engagement time, and exposure time for each engagement. Scoring standards varied as a function of the weapon system used, the range to the targets, and whether it was a single or combined engagement. Crews that did not qualify on the first gunnery run (700 of 1000 possible points and 7 of 10 go ratings) were required to rearm and reshoot the engagements they had failed.

Final live-fire data were collected on 6 V Corps crews and 12 VII Corps crews. In addition to the V Corps unit withdrawal, additional crews were lost because of early aviator transfers, medical groundings, changes in pilot-in-command status, and aviator transfers during the VII Corps range postponement. Four of the retained crews were in the control group and seven crews were in each of the experimental groups. Despite the aviator attrition, the retained crews in each group were approximately equal in age and relevant experience when they completed the AH-1F Aviator Questionnaire. However, there were substantial differences between the two Corps in the amounts of training received and the live-fire exercise conditions. For example, two of the V Corps crews were unable to qualify on Table VIII because of a shortage of usable ammunition. Therefore, the conclusions drawn from the project are based primarily on the VII Corps data.

Analyses of the live-fire data were completed during the current contract year. Although the results were not always statistically significant because of the small number of crews in each group, three tentative conclusions were drawn from the data. First, the FWS trained crews generally performed better than the control crews during the final live-fire exercise. The FWS trained crews had higher scores on the first gunnery run, had more crew qualifications on the first run, and required fewer gunnery runs to qualify than the control crews. Second, the performance of the two experimental groups was similar during the exercise. The small performance differences between them generally favored the group that trained quarterly. Third, significantly fewer rockets were required to achieve crew qualification by the experimental groups. However, some live-fire practice is still needed because not all the experimental group crews qualified on the first run. Instead of replacing live-fire practice, the FWS training probably prepares the crews for utilizing their limited range time more effectively.

A draft report documenting the method and results of the AH-1 FWS TEA was submitted to ARIARDA for review in March, 1991. The report was revised according to comments by the ARIARDA peer reviewers and submitted to ARIARDA in December 1991 (McAnulty).

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TRAINING EFFECTIVENESS ANALYSIS OF THE
AH-64A COMBAT MISSION SIMULATOR

Dr. David Hamilton, Project Director

Background

In response to a Department of the Army (DA) tasking in
1986, the Army Research Institute Aviation Research and
Development Activity (ARIARDA) initiated two training
effectiveness analyses (TEAs) of the AH-64A Combat Mission
Simulator (CMS). In 1988, the Department of Tactics and
Simulation (DOTS; formerly the Department of Gunnery and
Flight Systems) requested that the projects focus on the
acquisition and sustainment of helicopter gunnery skills in
the CMS. The DA tasking and the DOTS request, which are
discussed in detail in Cross and Gainer (1987) and in Kaempf
(1988), are summarized below.

DA Tasking

In 1986, DA tasked ARIARDA, through the Training and
Doctrine Command (TRADOC), to plan and initiate TEAs of each
of the Army's flight simulator systems. The TEAs were
intended to investigate the utilization and training
effectiveness of Army flight simulator systems in operational
field units a ' to provide the basis for developing effective
training strategies. In response to the tasking, ARIARDA and
Anacapa developed a research plan comprising a series of
related research projects (U.S. Army Research Institute,
1986). Each project was designed to investigate the
effectiveness of a flight simulator system for training a
specific set of tasks (e.g., weapons tasks, contact flight
tasks, and emergency flight tasks) in operational units.

DOTS Request

The quantities and types of munitions that operational
units need to attain and sustain weapon proficiency for all
Army weapon systems, including the AH-64A, are determined by
the Standards in Training Commission (STRAC). STRAC
publishes its recommendations for the types and quantities of
ammunition for aviation weapon systems in chapter 7 of DA
Pamphlet 350-38 (Department of the Army, 1990). Chapter 7
also specifies the percentage of aircrews that must be
qualified for the training readiness condition of the
operational unit. STRAC stresses making the maximum use of

aids, devices, simulators, simulations, and subcaliber firing to achieve weapon proficiency.

To provide a guide for unit commanders to meet the STRAC requirements and to ensure effective and efficient operation of all attack helicopters, DOTS publishes a training manual for helicopter gunnery (FM 1-140; Department of the Army, 1986). FM 1-140 defines the training requirements and performance standards for the Army's aerial gunnery training program. In 1988, DOTS published revisions to the manual (TC-1-140; USAAVNC, 1988). The revised manual contained significant changes to the crew gunnery training requirements and standards for the AH-64A aircraft. DOTS proposed to reduce training ammunition requirements by conducting all AH-64A crew gunnery training and qualification in the AH-64A CMS. No ammunition was provided for crew training and qualification; ammunition was provided only for training attack helicopter teams and conducting combined arms live-fire and joint air attack team exercises. In addition, the engagement time standards were eliminated and the target effect areas were made substantially smaller for gun and rocket engagements.

In a later revision of the gunnery manual (TC 1-140; USAAVNC, 1990), the proposal that all AH-64A crew gunnery be conducted in the CMS was dropped. The available training ammunition was redistributed among the gunnery tables, with more being allocated for the crew tables and less for the team tables. The gunnery standards remained substantially different and more difficult than those in FM 1-140.

While considering the effects of these changes on gunnery training and evaluation, STRAC requested that DOTS (a) evaluate the effectiveness of the CMS for training and sustaining crew gunnery skills, (b) acquire information on typical AH-64A gunnery performance, and (c) determine the effects that the changes in the gunnery standards had on performance. DOTS requested that ARIARDA conduct the research and ARIARDA agreed to focus the TEAs on gunnery issues. Two projects were designed to investigate CMS gunnery training: a TEA of the CMS for conducting crew gunnery initial qualification training and a TEA of the CMS for conducting crew gunnery proficiency sustainment training.

Coordination problems with the Apache Training Brigade at Fort Hood, Texas, halted the initial qualification project. Because no research was conducted on the project, the remainder of this summary focuses on the proficiency sustainment project.

Problem

The Army has made a significant investment in the development and acquisit'on of motion-based, visual flight and weapons simulators for use in training its rotary wing aviators. At the same time, operational unit commanders have been encouraged to reduce training ammunition requirements and to use the most efficient and effective mix of simulator and aircraft training. However, no empirical data existed to demonstrate the effectiveness of flight simulators in augmenting unit gunnery training. Empirical data were required to determine if flight simula ors could effectively train gunnery skills and to determine the extent that training conducted in simulacors could be used to conserve training resources such as aircraft flight time and live ammunition.

In addition, DOTS and STRAC wanted to provide unit commanders with a framewcrk for aerial gunnery training and evaluation that was realistic and achievable. However, there were insufficient empirical data to demonstrate the timing and accuracy that Army aviators were capable of achieving with the AH-64A weapon systems. Because total system performance is dependent on the interaction of the aircraft, its ammunition, its maintenance, and the skill and training of its crewmembers, AH-64A gunnery performance measures from an operational unit were needed to evaluate the changes made to the standards in TC -140.

Research Objectives

This research was designed to meet four objectives:
- determine the effectiveness of the CMS for sustaining crew gunnery ski:ls,
- obtain and describe measurements of AH-64A gunnery performance taken from Army aviators with experience levels that are typical of Army AH-64A units,
- analyze the gunnery performance to determine the difficulty of different gunnery standards, and
- identify the major factors influencing AH-64A gunnery performance.

Research Methodology

The research plan was divided into four phases: (1) initial gunnery performance evaluation, (2) CMS gunnery

training, (3) final gunnery performance evaluation, and
(4) analysis and documentation.

Initial Gunnery Performance Evaluation

During Phase 1, an initial evaluation of AH-64A crew
gunnery performance was conducted during a live-fire exercise
and in the CMS. The live-fire exercises were conducted
between 25 March and 26 May 1990 at the Dalton-Henson
Multipurpose Range Complex, Fort Hood, Texas. Measures of
target effect and engagement time performance were collected
on 30 crews from the 6th Cavalry Brigade Air Combat. The
data on crew gunnery performance were obtained from the Area
Weapons Scoring System, the squadron Standardization
Instructor Pilots, and the AH-64A videotape system. Over
1,700 data base records were produced that describe the
environmental conditions, the engagement time, and the target
effect of each gun, rocket, and missile engagement fired
during the exercise. In addition to the performance
measures, each of the participating aviators completed a
demographic questionnaire.

The initial CMS gunnery performance testing was
conducted between 23 and 30 June 1990. Each crew's gunnery
performance was evaluated during one day and one night
scenario conducted during a single 1.5-hour simulator
session. Target effect and engagement time performance were
obtained for each engagement from the ownship gunnery summary
report generated by the CMS and from videotapes of the
engagements taken with the AH-64A CMS videotape system.

CMS Gunnery Training

In Phase 2, crews received gunnery training depending on
their assignment to one of two groups: one that received
scenario-based gunnery training in the CMS and one restricted
from gunnery training in the CMS. The training was conducted
over a 6-month period to minimize the impact of crew
attrition. Of the 30 crews participating in the project, 16
were assigned to the CMS training group and 14 were assigned
to the no CMS training group. Between 1 July and 15
September 1990, each CMS gunnery crew received five scenario-
based gunnery training sessions in the CMS.

To document the frequency of other gunnery training
activities, a postflight debriefing form was prepared and
distributed to each project aviator. The aviators were
instructed to complete the forms after flights in the AH-64A

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aircraft or sessions in the CMS or Cockpit, Weapons, and
Emergency Procedures Trainer.

Final Gunnery Performance Evaluation

As in Phase 1, crew gunnery performance was again
measured in Phase 3 during a final live-fire exercise and in
the CMS. The final live-fire exercises were completed
between 12 and 26 September 1990. Of the initial 30 crews,
18 were retained until the end of the project (9 in each
training group). Because of limitations on ammunition and
range access, project crews were allowed to fire each gunnery
engagement only once for day conditions and once for night
conditions. Performance measures were recorded as described
in Phase 1. The final CMS performance evaluation was
completed between 21 and 29 September 1990.

Analysis and Documentation

During Phase 4, the data were analyzed, recommendations
developed, and the results reported. The effectiveness of
the CMS was evaluated by measuring the differential
performance of the training groups between the pretest and
posttest in the CMS and the live-fire exercises.

Results and Conclusions

The results of this research are fully described in two
reports: Hamilton (1991b) describes the results of the AH-
64A CMS TEA, and Hamilton (1991a) describes the results of
the gunnery performance and standards evaluation. The
results and conclusions presented in each report are
summarized below.

The analysis of the initial and final performance tests
conducted in the CMS showed that after five gunnery training
sessions, CMS performance was consistently (but not
significantly) improved in the experimental group. The
performance tests conducted on the live-fire range indicated
that both groups improved from the initial to final tests,
but the improvement could not be attributed to CMS training.
In skill sustainment research such as this, either the
experimental group's skills need to improve significantly or
the control group's skills need to decay significantly for
training effectiveness to be demonstrated. The time between
the initial and final tests, which was shortened to 6 months,
was insufficient to produce either significant improvement in

the experimental group or significant skill decay in the control group (Hamilton, 1991b).

The results of the gunnery performance evaluation support five conclusions (Hamilton, 1991a). First, the time standards expressed in terms of aircraft exposure time are difficult to measure. Second, the gun target effect is influenced significantly by target distance: engagements at less than 1700 m are above standards and engagements at greater than 1700 m are below standards. Third, the standards for missile target effect are inadequate to produce consistent evaluations of these engagements. Fourth, the target effect for rocket engagements supports the narrow cross-range width and elongated down-range length of the rocket boxes; however, the substantial reduction in the size of the boxes will significantly reduce the number of crews that attain the standards. Fifth, the distributions of rocket impacts show a consistent shift that indicates the majority of the rockets land right and short of the targets.

Recommendations

Two recommendations are presented on the basis of the AH-64A CMS TEA research results. First, if aircraft hours and other forms of gunnery training are funded at the levels observed in this research, CMS gunnery training may be required only on a quarterly basis. However, if the support for aircraft hours and other gunnery training is reduced, gunnery skills may decay in less than 6 months and additional CMS training will be required to maintain gunnery skills. Second, further research is required to investigate gunnery skill decay in proficient aviators over a 12- to 18-month period.

The results of the AH-64A gunnery and standards evaluation support four recommendations. First, exposure time standards should be changed to facilitate the collection of those measures. Second, the size of the rocket boxes for the M274 rounds should be increased from 100 by 400 m to 150 by 400 m. Third, a score sheet should be developed for the evaluation of HELLFIRE training missile engagements. Fourth, further research should be conducted (a) to determine the cause of the shifts observed in the distribution of rocket impacts and (b) to collect and analyze gunnery performance for AH-64A tasks not evaluated here and for aircraft other than the AH-64A.

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EFFECTIVENESS OF AIRNET IN TRAINING
COLLECTIVE ARTEP TASKS

Dr. Beth W. Smith and Dr. Kenneth D. Cross,
Project Directors

Background

Evaluations by the Directorate of Combat Developments (1982, 1983, 1986) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, identified several deficiencies in the training of Army aviators to perform collective tasks. Specifically, the Battlefield Development Plan (1986) identified training deficiencies in air-to-air, antiarmor, sustained aviation, and air assault operations, and in the suppression of enemy air defense, special operations missions, aerial reconnaissance, combat maneuvers, search and rescue operations, target acquisition and handover, and aircraft survivability. The Battlefield Development Plan attributed the deficiencies to constraints that prevent adequate training on collective tasks in the aircraft. Among the most important constraints identified are the following:

- training ranges are insufficient in number, size, and topographic diversity to conduct effective collective-task training,

- the high cost of aircraft, fuel, ordnance, and logistic support limits the frequency of collective-task training exercises, and

- collective training in the aircraft under realistic conditions increases the likelihood of accidents.

Because of the constraints on live training in the aircraft, the use of training devices was identified as an alternative method of collective-task training. In 1987, the USAAVNC established a Memorandum of Understanding (MOU) with the Defense Advance Research Projects Agency (DARPA) to develop a prototype combined-arms tactical trainer that can eliminate some or all of the deficiencies in collective-task training. The MOU led to the development of the aviation networked simulator system (AIRNET).

AIRNET is a research and development tool and serves as the proof-of-concept for the simulation networking of rotary wing aircraft. Development of the device was planned in three phases: Fully Reconfigurable Experimental Device (FRED), Generic, and AIRNET Specific. The production training device will be called the Aviation Combined Arms Tactical Trainer (AVCATT).

In June 1988, the Directorate of Training and Doctrine (DOTD) at the USAAVNC tasked the Army Research Institute Aviation Research and Development Activity (ARIARDA) to assist in evaluating AIRNET for training the Army Training and Evaluation Program/Mission Training Plan (ARTEP/MTP) tasks. In addition, ARIARDA was tasked to provide recommendations about design modifications that are likely to increase AIRNET's training effectiveness. Finally, the tasking requested that evaluations be conducted for each phase of development. In September 1988, ARIARDA directed Anacapa Sciences to design and conduct evaluations of the AIRNET device.

Research Objectives

The general objective of this research area is to evaluate the AIRNET device for training collective ARTEP/MTP tasks. There are four specific objectives for the research projects in this area:

- identify the ARTEP/MTP tasks for the Attack Helicopter Company and the Air Cavalry/Reconnaissance Troop that can be performed in AIRNET,

- evaluate the degree to which functions, segments, and phases of the ARTEP/MTP tasks can be realistically performed in AIRNET,

- determine the modifications to system features required to accommodate the ARTEP/MTP tasks that cannot be performed in AIRNET, and

- identify the navigation-related skills and mission tasks from the Enlisted Aeroscout Observer Course (EAOC) that can be adequately trained in AIRNET.

Research Approach

Three projects were designed to meet the objectives of this research area. One project was completed during the 1990 contract year and is summarized in this report under the title of "Assessment of Army Aviators' Ability to Perform Individual and Collective Tasks in AIRNET." The other two projects are discussed in the following sections.

Effectiveness of AIRNET in Training Collective ARTEP Tasks

In the first project, information about the training value of AIRNET's developmental phases was obtained by evaluating experienced crewmembers' ability to perform

selected flying tasks in each device. The rationale for this approach is that effective training on a task cannot be accomplished in AIRNET if an experienced crewmember who performs it routinely in the aircraft cannot perform it adequately in AIRNET.

The Aircrew Training Manual (ATM) and the ARTEP/MTP tasks for the Attack Helicopter Company and Air Cavalry Reconnaissance Troop were reviewed to select representative collective and individual tasks. Performance rating scales based on selected ATM and ARTEP/MTP tasks were developed to identify inadequate system features, and questionnaires were developed to obtain user opinions about individual and mission task performance and the technical capabilities of AIRNET. Finally, a training scenario was developed that includes the selected collective and individual tasks.

As the FRED and Generic phases of the AIRNET device were installed, experienced aviators performed the evaluation scenario. Researchers and instructor pilots rated the aviators' task performance in the devices and the participating aviators completed the questionnaires to provide input on device deficiencies and needed improvements.

Evaluation of the Aeroscout Observer Course

In the second project, a training effectiveness evaluation was conducted to determine the feasibility of providing skill acquisition training in AIRNET. Forty-six students from the EAOC were divided into three training groups for the evaluation. One group of EAOC students was trained in the aircraft, one group was trained in the classroom, and one group was trained in the Generic AIRNET device. Differences in the effectiveness of the training procedures were determined by comparing their performance on navigation and mission tasks in the OH-58 aircraft. Questionnaires were developed and administered to obtain user information on navigation and mission task performance and on technical performance issues related to acquisition training in AIRNET.

Results

Effectiveness of AIRNET in Training Collective ARTEP Tasks

The research on the FRED and Generic AIRNET devices was conducted during previous contract years. The evaluation of the FRED resulted in improvements to the flight

characteristics and weapon systems included in the Generic
AIRNET configuration. Evaluation of the Generic AIRNET
device resulted in the identification of several system
deficiencies that hindered adequate task performance.
Several design features were directly related to the
inadequate performance of 70% of the collective tasks.
Experienced aviators who participated in the evaluation
perceived the Generic AIRNET as inadequate for training
operational aviation units.

A preliminary report (Thomas, 1989) of the evaluation was
submitted to DOTD during the third contract year. During the
fourth contract year, the research approach and preliminary
summary data were presented at the second annual conference on
simulation sponsored by the Royal Aeronautical Society in
London, England (Thomas & Gainer, 1990). During the current
contract year, further data analyses were conducted and a
final project report (Smith & Cross, 1991b) was prepared and
submitted to ARIARDA.

Evaluation of the Aeroscout Observer Course

Student and instructor pilot responses on the
questionnaire suggest that AIRNET training may be beneficial
for two mission tasks (call for indirect fire and adjust
indirect fire), but the training benefits were not large
enough to have a statistically significant effect on either
the aircraft hours required to reach proficiency or the
students' grades on the final checkride. Summary data tables
were provided to DOTD at the end of the fourth contract year
to assist in cost-benefit estimates of conducting training in
AIRNET. During the current contract year, a draft report
(Smith & Cross, 1991a) about this research project was
prepared and submitted for review.

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SIMULATOR COMPLEXITY TEST BED FOR
THE PHOTO BASED MODELING SYSTEM

Mr. Gary W. Coker, Project Director

Background

In 1992, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, is scheduled to take delivery of one of the most complex and powerful helicopter flight simulators ever procured by the Army. The Simulator Complexity Test Bed (SCTB) simulator is a modular system that allows the rapid reconfiguration of system parameters to produce both high- and low-fidelity simulations of various aspects of the AH-64 helicopter mission. The system will use a fiber-optic, helmet-mounted display device with eye-tracking area-of-interest insets, a high performance image generator (IG) with three hardware eyepoints, tactical environment software capable of providing multiple simultaneous simulations of intelligent forces using rule-based artificial intelligence, and other advanced technology.

The SCTB simulator is the principal component of the Simulator Training Research Advanced Testbed for Aviation (STRATA) research program under development at ARIARDA. The STRATA program is designed to answer research questions about the amount of simulation fidelity required to train specific tasks in the AH-64 helicopter. In addition, the SCTB simulator capabilities will allow ARIARDA researchers to conduct experiments in areas such as air-to-air combat that have been difficult or impossible to conduct with less advanced systems.

Need

This project was initiated in response to a tasking by ARIARDA to Anacapa Sciences to provide data base modeling support for the SCTB research simulator. When completed in 1992, the SCTB simulator will provide state-of-the-art simulation fidelity capabilities in both the visual imagery it can generate and the accuracy and complexity of the tactical scenarios it can simulate. Utilizing the full capabilities of the simulator will require a skilled team of computer scientists to provide data base modeling and tactical programming support. The SCTB system will be delivered with an off-the-shelf data base of the state of Arizona. However, the Arizona data base will require modifications for use in the STRATA program. In addition,

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new data bases for other environments (e.g., Fort Rucker) and ongoing data base modeling will be required as new experiments are planned and executed.

Project Objectives

The primary objective of this project is to provide data base modeling support to the SCTB project. The specific objectives of this project include:

- training Anacapa personnel in the theory and techniques associated with flight simulation and data base modeling, and
- providing an in-house data base modeling capability for the SCTB research project.

Approach

Anacapa computer scientists will build computer models of real-world objects (e.g., terrain, aircraft, ground vehicles, weapons systems, and cultural features) for visual data bases needed to meet the research requirements. The work will include modifying the Arizona data base and building completely new models and data bases, such as Hanchey Army Heliport (AHP). Models will be built to meet the following requirements:

- fully utilize the capabilities of the SCTB simulator by providing the highest fidelity possible,
- provide multiple levels of detail that can be degraded to address simulator fidelity research questions, and
- use modular construction to allow for rapid reconfiguration.

Work Completed

This project was initiated in October 1989. Work completed during the previous contract year included data base modeling training for the Anacapa computer scientists and developing a model of Hanchey AHP.

The modeling training was divided into three phases. In the first phase, Anacapa personnel collected and reviewed all the available information related to the SCTB program. In the second training phase, a 6-hour seminar entitled "Basics of Data Base Modeling" was developed and presented to all ARIARDA and Anacapa personnel currently involved in flight simulation projects. The third training phase consisted of

10 weeks of intensive data base modeling training on the
SCTB's ESIG-1000 IG. For more detailed information on the
modeling training, see Coker (1991).

In May 1990, work began on modeling Hanchey AHP at Fort
Rucker, Alabama. The following work was completed during the
previous contract year:
- data base design for the heliport,
- geometry development, and
- inter- and intrastructure priority design and
  development.

Work completed during the current contract year includes
refining the Hanchey AHP model, developing additional data
base modeling software tools, developing a documentation
standard for data base models, receiving additional simulator
system training for the Anacapa computer scientists, and
investigating action items concerning data base modeling
issues.

Hanchey Model Refinement

The SCTB data base modeling system was installed at Fort
Rucker during the week of 8 October 1990. The modelers
resumed construction of the Hanchey AHP by defining modeling
objectives. These objectives included developing multiple
levels of detail (LODs) for each model, acquiring and
applying photo-based texture maps to the models, and
integrating the models into a single data base terrain
square. The initial work consisted of visiting Hanchey AHP
and shooting photographs to be used as texture maps. The
maps were then digitized using the modeling system's digital
camera and applied to the models. The modelers then began
developing additional LODs for the individual models. A
minimum of three versions of each model was developed and
associated transition ranges (the distance at which a
different LOD is displayed) and fade bands (the range inside
which two LODs are processed simultaneously) were defined.

The development of multiple LODs for each model
completed the geometry requirements for the Hanchey AHP
buildings. Collision volumes and height above terrain
structures were added to each model. A terrain square was
developed that closely matches the actual terrain elevations
found near Hanchey AHP. The modelers developed additional
models to be used as airfield clutter, including tugs and
fire trucks. All models were optimized for color and texture
fidelity as well as polygon efficiency. A global priority

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solution was developed so that all models would occult properly. The individual models were integrated into a single data base section in preparation for adding Hanchey AHP to the Arizona data base.

Development of Data Base Modeling Tools

In addition to work on the Hanchey model, Anacapa computer scientists also developed modeling software tools and techniques. After procuring a three-dimensional Computer Aided Design (CAD) program designed for personal computers (PCs), a program was developed for automatically translating from the data base modeling system format to the CAD format. This program provides the capability for off-line viewing, debugging, and documenting data base models. Another program, called VIEWTEX, was developed that allows each modeler to view texture maps quickly on a PC without running the Photo-Based Modeling System program, which can be used only by a single user at a time. A still-video camera and a video-digitizer board for the PC were also acquired. This equipment allows faster acquisition of texture maps because the time spent in developing film is eliminated. The VIEWTEX program has been modified to provide printing and translation capabilities for images obtained with the still-video camera.

Development of a Documentation Standard

Anacapa computer scientists also developed a documentation standard for data base models. The standard consists of a checklist form and a standard documentation format. It includes guidelines for data base structure and priority diagrams, text descriptions, tables for color, texture, IG timing, polygon count, and drawings of geometry and texture applications. The standard is now used for developing all new data base models.

Simulation System Training

During June 1991, Anacapa computer scientists received 3 weeks of training on the SCTB simulation system at the simulator manufacturing site. The modelers studied the following topics during the training:

- use of the IG microcode utility and the Gould and ESIG-1000 operating systems;
- system hardware operation;
- Real-Time System software and its interface to the IG;

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- methods for modifying system software modules written in FORTRAN;
- Computer Test System software and global system variables;
- operation of the Experimenter/Operator Station and Blue/Red Team Station;
- operation of the Database Management System component of the Interactive Tactical Environment Management System; and
- use of Data Recording and Analysis software tools.

The modelers also participated in the Acceptance Test Procedures for the Arizona data base.

Definition of Modeling Issues

Throughout the contract year, Anacapa researchers and computer scientists defined action items related to data base modeling issues. These items include (a) the definition of data base modeling requirements for initial SCTB experiments, (b) the development of SCTB research topics, (c) an investigation of data base portability issues, and (d) planning for the use and modification of the Arizona data base to be supplied with the simulator.

Beginning in April 1991, the modelers defined data base modeling requirements for the first experiment planned for the SCTB simulator by ARIARDA researchers. The experiment is designed to investigate simulator fidelity issues by requiring subjects to fly a mission using three different IG system emulations. The modelers obtained specifications for each of the IGs to be emulated and determined rough budgets for each of the required data bases' polygon count, object density and fidelity, moving models, and special effects, such as z-offset texture, animation, and texture motion. The modelers developed the data base budgets using ratios that users of the individual IGs would likely use, but could not make firm budgeting decisions until an area of the Arizona data base is chosen to serve as the ESIG-1000 (high fidelity) version of the experimental gaming area. At the end of the contract year, this area had not been selected.

Beginning in May 1991, Anacapa researchers developed research plans for the SCTB simulator. Research synopses for the following 13 topics were delivered to ARIARDA in June:
- accident scenario training,
- aerial gunnery training research,
- aircraft accident simulation,

- an investigation of tactical decision making by Army rotary wing aviators,
- analysis of helmet-mounted displays in rotary wing aircraft,
- assessment of the use and benefits of advanced mission planning and rehearsal systems,
- aviator workload research,
- development and evaluation methods for training unmanned aerial vehicle operators in a simulator,
- development of map interpretation and terrain analysis training materials,
- evaluation of air-to-air combat tactics and training strategies,
- helmet-mounted display symbology,
- optimal training strategies for aviators using visual systems with a limited field of view, and
- visual requirements for evaluating aviator proficiency in simulators.

Throughout the contract year, Anacapa computer scientists investigated the portability of data bases both to and from the SCTB simulator. By developing a capability for using models and data bases from other systems on the SCTB system and vice versa, the efficiency of SCTB research can be enhanced by reducing the amount of time required for custom model and data base development. During November 1990, the modelers developed a document delineating procedures used in data base model development to ident fy system-independent products of the process. The modelers found a very low level of data base portability between systems except for the Multi-Gen modeling software developed by Software Systems. By using Multi-Gen's standard file format, data base models can be used on multiple target IGs. Throughout the curre .. year, Anacapa modelers monitored the development of Mult -Gen for the Evans & Sutherland line of IGs.

Throughout the current year, the modelers cont nued studying the Arizona data base. During the June 1991 trip to the manufacturer's site, the modelers viewed the data base on the ESIG-1000 IG for the first time. They gained experience loading the Arizona data base, using the IG a .d Gould operating systems, and examining the Arizon data base. The modelers used the ESIG-1000's flybox to fly around all major features of the data base. The modelers also examined all the target models in the data base, including helicopters, fixed wing aircraft, and ground vehicles.

Upon returning to Fort Rucker and receiving the Ada source code for the Arizona data base, the modelers began modifying the target models in two ways: (a) converting the rotors on the helicopters and the turrets on the tanks from Dynamic Coordinate Systems to Static Model Systems, and (b) developing lower fidelity versions of the models. Throughout the year, Anacapa modelers studied implementation specifics of the Arizona data base, such as terrain triangle edge length, z-quantization values, basis set definitions, color and texture assignments, fidelity of patch areas, and the specifics of individual feature models. At the end of the year, the modelers were thoroughly familiar with the data base and were able to modify the data base to meet experimental requirements.

Future Requirements

The SCTB simulator provides the capability for innovative research on simulation issues. However, the STRATA program will require the development of custom data bases and tactical scenarios. Specifically, the Arizona data base must be modified to implement the initial and subsequent SCTB experimental designs. Also, the Hanchey AHP model must be integrated into an area of the Arizona data base to support experiments requiring flight around the airfield.

Reference

Coker, G. W. (1991, June). Simulator complexity test bed for the photo based modeling system. In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1990 annual summary report (Technical Report 930, pp. 89-92). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A241 134)

TECHNICAL ADVISORY SERVICE: SUPPORT TO THE UH-1
TRAINING RESEARCH SIMULATOR (UH1TRS)

Mr. Richard J. Jamison, Technical Advisor

Background

The U.S. Army Research Institute Aviation Research and
Development Activity (ARIARDA) has initiated a low cost
visual helicopter simulator test bed research program using
the cockpit and motion base system of a UH-1 Instrument
Flight Simulator (UH1FS). The current version of the test
bed is configured as a UH-1 (Huey) helicopter and is called
the UH-1 Training Research Simulator (UH1TRS). The existing
high fidelity UH1FS cockpit was retrofitted with three
collimated out-the-window displays presenting one channel of
imagery to each of the two front windows and the second
channel to the right side window.

To save development costs, only those instruments
required for primary phase flight training are active in the
UH1TRS. The instruments include the attitude gyro, airspeed
indicator, altimeter, vertical speed indicator, turn and bank
indicator, and torque meter. The simulator cockpit includes
instructional support features for use by the instructor
pilot (IP), such as freeze/reset, begin/stop, a prerecorded
demonstration flight, and an instant replay that repeats the
last 75 seconds of flight. Aural cues are provided to
support flight training. Engine, transmission, and main
rotor sounds vary in loudness as a function of airspeed and
power setting; the wind sound varies only as a function of
airspeed. The sound of landing skids scraping the ground is
simulated as a cue for the aircraft moving while on the
ground.

From the control console, the simulator operator can
communicate with the cockpit via an intercom system to
control the training session. The operator can activate the
simulator motion base, change initial conditions (e.g.,
aircraft location on the data base), add wind or turbulence,
control training conditions (e.g., record/playback of a
demonstration flight), or print a graphic plot of a recorded
flight parameter, such as altitude, as a function of time.

Before Anacapa began supporting the UH1TRS research,
four transfer-of-training (TOT) experiments had been
completed. Each TOT experiment required 10 randomly selected
initial entry rotary wing (IERW) student pilots (SPs) to
complete eight contact phase maneuvers to standard in the

UH1TRS. Iteration counts were recorded for each maneuver. When the SP completed three successive iteration counts to standard, pretraining was considered complete for that maneuver. With the exception of the fourth experiment, which substituted 9 hours of UH1TRS time for 11 hours of flight time, the experimental group SPs joined the remainder of the class (control group SPs) on the first day at the flight line. Iterations to criterion were recorded on the eight selected maneuvers for each SP in the aircraft.

A transfer effectiveness ratio (TER) was calculated for each maneuver in each experiment. Negative TERs were found in some of the experiments. However, overall data from the four experiments showed that the experimental group SPs required fewer iterations in the aircraft and that a positive TER was achieved for each maneuver.

Research Approach

Multiple experiments are planned for the UH1TRS to evaluate the effectiveness of the simulator for training IERW students, to determine how much fidelity is required for effective simulation, and to determine the optimum combination of aircraft and simulator training. Each experiment will follow the basic paradigm described for the previous experiments. IERW students will be assigned to either a control or an experimental group, differential training will be conducted for the groups, and student performance in the aircraft will be measured following the initial training.

Support Provided

During the previous contract year, Anacapa personnel supported two research projects in the UH1TRS. The first experiment was conducted to determine the contribution of motion to the effectiveness of the UH1TRS for training IERW students in primary maneuvers. The maneuvers selected for training were takeoff to hover, stationary hover, hover taxi, hover turn, and land from a hover. Twelve warrant officer candidates who had not yet started IERW training were selected as SPs. Instruction was provided by IPs qualified in the UH-1 aircraft. The results indicate that the motion base does not facilitate student training in the UH1TRS.

The second experiment evaluated the performance of SPs using an automated hover trainer (AHT) in the UH1TRS. The AHT was designed to aid IERW SPs in learning basic hovering skills with minimal IP supervision. The AHT utilizes

artificial intelligence to determine the degree of proficiency at which an SP is performing a hovering maneuver. At the beginning of the maneuver, the flight controls are degraded to the point that massive inputs are required to elicit a response from the UH1TRS. As the SP learns to control the UH1TRS within school standards, the artificial intelligence program increases the sensitivity of the controls until the SP is flying the true aeromodel. The results indicate that SPs can be trained in hover related maneuvers utilizing the artificial intelligence program.

During the current contract year, Anacapa personnel supported a TOT experiment to determine the effectiveness of the AHT. In this experiment, the performance of SPs trained on the AHT was evaluated in the UH-1 helicopter.

Anacapa personnel provided the following support to the AHT training effectiveness experiment:

- attended meetings and assisted in planning the experiment,

- evaluated software programs developed for the UH1TRS,

- operated the UH1TRS and collected data during the training phase of the experiment,

- collected data from the flightline during the transfer phase of the experiment, and

- analyzed data and constructed briefing charts.

Results

The results of the TOT experiment indicate that there is positive transfer of training from the AHT to the UH-1 helicopter.

TECHNICAL ADVISORY SERVICE: SUPPORT TO
PILOT NIGHT VISION SYSTEM RESEARCH

Mr. Gary Coker and Ms. Laura Fulford, Technical Advisors

Background

This project was initiated in response to a tasking by
the U.S. Army Research Institute Aviation Research and
Development Activity (ARIARDA) to provide computer
programming support for the pilot's night vision system
(PNVS) research being conducted by ARIARDA. The research
investigates the feasibility of the enhanced helicopter
indirect imaging systems to be used in conjunction with or as
an alternative to current systems, such as the PNVS used in
the AH-64 helicopter.

The work focuses on the development of a simulated
horizontal situation display (HSD) that presents a wide
field-of-view, circular, fish-eye image. Initial experiments
will consist of three phases: (a) measurement of subject
responses to presentation of static HSD imagery,
(b) measurement of subject responses to open loop moving HSD
imagery that represents vehicle movement, and (c) requiring
subjects to perform threat evasion and attack tasks during
closed loop flight using only the HSD imagery.

Programming support for this project is required in the
following areas:
 • developing HSD graphics for use as stimuli,
 • recording and analyzing subject response data,
 • evaluating and selecting software and hardware, and
 • programming helicopter responses.

Approach

The initial hardware configuration for the project
consists of a personal computer (PC) with a Systems Research
Laboratory (SRL) LabPak analog-to-digital data acquisition
board and Video Graphics Array (VGA) graphics board. This
equipment will be used for Phase 1 and perhaps Phase 2.
Phase 3 will utilize a Silicon Graphics 2400 Turbo
workstation for graphics generation. The 2400 Turbo will be
controlled by the PC over a serial communications line.
Subject input for all three phases will come from the ATC-
112H helicopter instrument flight rules (IFR) flight
simulator controls connected to the PC's LabPak board.

Support Provided

In April 1991, Anacapa Sciences personnel began developing computer programs to control Phase 1 experiments. The programs present two static simulated horizontal situation display (HSD) images to the subjects, separated by an interval in which the screen is blank. The subjects make helicopter control inputs upon seeing the second image. An interrupt routine was developed to perform 3-channel data acquisition from the LabPak board connected to the ATC. The routine was tested with acquisition rates up to 1000 Hz. Routines were also generated for quickly loading stimulus graphics screens into the VGA memory and for blanking the screen during each trial. Furthermore, user interface routines were developed for moving crosshairs and other graphics cursors in response to subject input. In August 1991, the routines were integrated into one main program that included a procedure to write subject responses to a file.

As the result of a meeting between ARIARDA researchers and Anacapa technical advisors in August 1991, the following decisions were made:

- The project will implement the fast Video Seven 1024i video card for Phase 1 and 2.

- The graphic screens will use 640 by 350 enhanced graphics adapter (EGA) resolution so that the images can be do le buffered.

- The technical advisor will look into acquiring animation software, either stand alone or compiler libraries, for use in Phase 2.

In response to the decisions made, the main program was modified to load two 640 by 350 EGA image files into video memory instead of one 640 by 480 VGA image file. This modification was needed to meet the timing requirements for the interval between the two static simulated horizontal situation display images.

Future Requirements

At the end of the current contract year, the LabPak data acquisition board would not deliver full 12-bit resolution from each channel. Therefore, no experiments for Phase 1 had been conducted. A gain boost circuit must be implemented to solve the LabPak problem. When the problem is corrected, the computer programs for Phase 1 can be fully tested and

preparation for initial subject trials can begin. After the
Phase 1 experiments have been completed, support will be
required for the experiments in Phases 2 and 3.

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SUMMARY OF PREVIOUS CONTRACT YEAR RESEARCH

Work on contract number MDA903-87-C-0523 began on 9 October 1986. At the end of each of the first 4 years of the contract, Anacapa Sciences submitted an annual summary report of the research activities and achievements for that year (Aldrich & McAnulty, 1988; McAnulty & Aldrich, 1989; McAnulty, 1990, 1991). This section of the final summary report presents abbreviated descriptions of the projects completed during the first 4 years and not reported as part of the continuing research conducted during the final contract year. Each abbreviated summary includes a reference to the annual report in which it is fully summarized and references to any reports or products that resulted from the project.

The abbreviated summaries are similar in format to the complete summaries in the first section, but typically contain less detail. Although some of the abbreviated summaries begin with a background section, most of them begin with a brief statement of the purpose of the research project(s). The statement of purpose is followed by a brief description of the research approach or method. The last part of the summary presents the results or products of the project.

In addition to the research that continued into the final contract year, Anacapa Sciences personnel completed 23 research or development projects and 14 technical advisory services during the first four years of the contract. Sixteen of the summaries in this section describe individual projects. Three of the summaries describe research areas that are divided into 7 discrete projects. One summary describes all the technical advisory services.

The research projects during the first 4 years of the contract were conducted in all four of the ARIARDA research domains. The first 5 summaries describe 6 projects in the emerging systems domain. The sixth and seventh summaries describe 1 project in manpower and personnel and 1 in aviation safety. The next 12 summaries describe 15 projects in the aviation training domain. The final summary presents a general description of the technical advisory services performed and lists each of the projects that were supported.

References

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    U.S. Army Research Institute for the Behavioral and
    Social Sciences. (AD A241 134)

TAWL OPERATOR SIMULATION SYSTEM (TOSS) VERSION 3.0

Ms. Laura Fulford, Project Director

Purpose

The primary purpose of this project was to develop a software system that (a) allows model changes without rewriting and recompiling the software, (b) executes any of the workload prediction models developed with the refined task analysis/workload (TAWL) methodology (see Hamilton & Bierbaum, 1990), and (c) can be used directly by workload analysts. In addition, the software should run on widely available computers and be written in a language that is easy to modify.

Approach

The TAWL operator simulation system (TOSS) software was designed (a) to store all model information peculiar to a specific system in computer data files, (b) to include a data base management system with specialized routines, and (c) to have a simple and consistent user-interface so that workload analysts can directly manipulate the software. The software system was written in the Turbo Pascal programming language and runs on any IBM AT compatible computer.

Results

During the contract, version 3.0 of TOSS was developed to accommodate up to four crewmembers instead of the previous maximum of two and to have a more consistent user interface. On 21 February 1990, the final versions of TOSS 3.0 User's Guide and software were delivered to ARIARDA. The development of TOSS 3.0 is discussed in detail in Fulford (1990) and Fulford (1991).

References

Fulford, L. A. (1990). Development of a task analysis/ workload operator simulation system (TOSS). In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1989 annual summary report (Technical Report 884, pp.5-10). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A221 657)

Fulford, L. A. (1991). Development of a task analysis/ workload operator simulation system (TOSS). In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1990 annual summary report Technical Report 930, pp.3-8). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences. (AD A241 134)

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VALIDATION OF THE LHX WORKLOAD PREDICTION MODEL

Mr. Theodore B. Aldrich, Project Director

Purpose

Anacapa Sciences researchers, under a previous contract to the U.S. Army Research Institute Aviation Research and Development Activity, developed a workload prediction methodology and produced one- and two-crewmember models for the proposed family of light helicopters (LHX) program (Aldrich, Szabo, & Craddock, 1986). The objectives of this project were to evaluate the validity of (a) the methods and scales used in the models and (b) the predictions generated by the models.

Approach

A three phase approach was developed to meet the research objectives (Aldrich & Szabo, 1986). In Phase 1, a survey of human factors scientists was planned (a) to derive equal-interval workload rating scales to replace the ordinal scales used in the original workload analyses, and (b) to estimate the consistency of the ratings used to construct the scales. A second survey, asking the scientists to use the scales to rate the workload of the model tasks, was planned to estimate the interrater reliability of workload ratings in the model. In Phase 2, full- and part-mission simulation research was planned to validate the predictions generated by the models. Finally, the information gathered during the validation research would be used to refine the model's predictions in Phase 3.

Results

During the second contract year, the first survey planned for Phase 1 was conducted. The data were used to construct equal-interval workload rating scales. The measures of rater concordance indicated moderate agreement among the raters. The scales did not differ substantially from the ordinal scales and were integrated into the models. The second survey planned for Phase 1 was not conducted because of scheduling problems with Phase 2. Phase 2 was scheduled to begin in October 1988 at the Crew Station Research and Development Facility (CSRDF) at NASA Ames, California, but the CSRDF simulation planners postponed the Phase 2 research indefinitely. Phases 2 and 3 of the project

were discontinued in April 1989. The project is summarized in Aldrich (1990).

References

Aldrich, T. B. (1990, March). Validation of the LHX workload prediction model. In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1989 annual summary report (Technical Report 884, pp. 25-29). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A221 657)

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UH/MH-60 AND CH/MH-47 TASK/WORKLOAD ANALYSES

Mr. Carl R. Bierbaum, Project Director

Purpose

The overall objective of this research area was to determine the effect that the MH-60K and MH-47E integrated cockpit modifications will have on the workload of UH-60A and CH-47D crewmembers.

Approach

The UH/MH-60 and CH/MH-47 workload analyses used the Task Analysis/Workload (TAWL) methodology (e.g., Hamilton, Bierbaum, & Fulford, 1990) and was divided into two projects. In the first project, a mission/task analysis was conducted of UH-60A and MH-60K workload and a computer model of the crewmember workload was developed. The workload prediction model TAWL Operator Simulation System (TOSS) was exercised to compare the predicted UH-60A crew workload with the MH-60K crew workload. In the second project, the same process was used to analyze and compare the predicted CH-47D crew workload with the MH-47E crew workload.

Results

Under the conditions assumed during model development (e.g., proficient operators, optimal weather conditions), neither the UH-60A, MH-60K, CH-47D, nor MH-47E placed excessive workload demands on its operators. Four reports (Bierbaum & Aldrich, 1990; Bierbaum, Szabo, & Aldrich, 1989; Bierbaum & Hamilton, 1990, 1991) were prepared and submitted to ARIARDA to document this research. The research is fully summarized in Bierbaum (1991).

References

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Bierbaum, C. R., & Aldrich, T. B. (1990, February). <u>Task analysis of the CH-47D mission and decision rules for developing a CH-47D workload prediction model. Volume I: Summary report</u> (Research Product 90-10a). (AD A221 969) <u>Volume II: Appendixes F through I</u> (Research Product 90-10b). (AD A221 805) Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

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DESIGN AND APPLICATION OF FLIGHT SYMBOLOGY

Dr. Richard D. Weeter, Project Director

Purpose

The objectives of this project were to develop a methodology for evaluating aircraft display symbology and to conduct empirical evaluations of the existing AH-64A pilot night vision system (PNVS) symbology.

Approach

Following a review of the literature, a selective visual attention approach was chosen to evaluate the PNVS symbology. The cueing procedures for the cued line-of-sight (LOS) symbol in the AH-64A PNVS symbology set were selected for the initial evaluation. Three experiments were designed to address differences in the one- and two-dot conditions, differences in presentation duration, the effects of the secondary cueing meaning, and the effects of practice on cueing accuracy. In addition, the experiments were designed as a test of the selective attention paradigm for evaluating symbology design.

Results

The results of the three experiments indicate that (a) the two cueing methods (one- and two-dot) are differentially effective in cueing shifts of visual attention at short presentation durations, (b) the ability to use the cues improves with practice, and (c) the secondary purpose of the cueing dots significantly interferes with their primary purpose. In addition, the ability of the selective visual attention paradigm to detect these effects indicates that it is an appropriate method for evaluating some aspects of existing and proposed aircraft display symbology formats.

This research area is fully summarized in Weeter (1991). The results of the literature review are reported in Weeter (1990) and the cueing procedure experiments are reported in Weeter and McAnulty (1990).

References

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A SURVEY OF HUMAN FACTORS METHODOLOGIES AND MODELS FOR IMPROVING THE MAINTAINABILITY DESIGN OF EMERGING ARMY AVIATION SYSTEMS

Dr. John W. Ruffner, Project Director

Purpose

The objective of this project was to conduct a literature review to identify and evaluate methodologies and computer simulation models that may be useful for improving the maintainability design of emerging Army aviation systems.

Approach

An extensive review of the literature was conducted on the topics of maintenance, maintainability design, comparability methodologies, and operator and maintainer behavioral simulation models. Three comparability methodologies and seven behavioral simulation models were discussed and critically evaluated with respect to their utility for improving maintainability design.

Results

The results of the literature review indicate that maintainer behavioral simulation models, such as Crew Chief and Profile, have the highest utility for improving maintainability design. Criteria were identified for developing a comprehensive methodology or model of maintainer performance and workload that can be used to predict maintainability during the early stages of Army aviation system development. In addition, critical issues that should be addressed by a program of research on Army aviation system maintainability requirements were identified and discussed.

This research area is fully summarized in Ruffner (1991). The results of the literature review are summarized in Ruffner (1990).

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EVALUATION OF A PEER COMPARISON PROGRAM
FOR THE OFFICER ADVANCED COURSE

Dr. D. Michael McAnulty, Project Director

Purpose

This research was conducted to develop a new method for selecting aviation officer course graduates for honors on the basis of their military attributes in addition to their academic performance. The purpose of the new method was to motivate students to maximize their efforts during the course and to identify students who have high potential as aviation officers.

Approach

Senior Army aviation officers were surveyed to identify five military qualities that were most important to the performance of Army aviators and were most likely to be demonstrated during the Aviation Officer Advanced Course (AVNOAC). A peer comparison (PC) procedure was developed that was a combination of the peer nomination and peer ranking methods and the psychophysical scaling technique of paired comparisons. On the PC form, class members nominated and ranked five of their peers on their potential as aviation officers and then compared each pair of nominees on each of the five military qualities. The PC procedure was administered twice on an experimental basis in each of two AVNOAC classes. Student critiques and faculty advisor ratings were also collected at the end of each course.

Results

The results of the experimental administrations indicate that the PC procedure is easy to use and produces highly reliable results, both in terms of the internal consistency of the PC procedure components and of the stability of the evaluations over 1- and 3-month periods. The results also indicate a consensus among the class members about which peers have the highest potential as aviation officers. The students reported that the peer evaluation caused many of them to improve their military decorum during the AVNOAC, but they generally had a negative reaction to the procedure.

This research project is fully summarized in McAnulty (1990a) and is reported in detail in McAnulty (1990b).

References

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ACCIDENT DATA BASE ANALYSIS

Mr. Joseph L. Zeller, Jr., Project Director

Background

This research project was conducted to determine if aircrew coordination errors were potential causal factors in Army helicopter accidents that were attributed to human error and to classify the causal aircrew coordination errors into types.

Research Approach

Two Anacapa Sciences analysts independently reviewed all the Army rotary wing accidents attributed to human error that occurred between October 1983 and June 1989. The accident data were retrieved from the computerized accident data base of the U.S. Army Safety Center's (USASC) Army Safety Management Information System (ASMIS). The analysts were both former Army aviators who had extensive accident investigation experience. In the initial analysis, each analyst rated the degree to which crew coordination errors contributed to each accident. In a more detailed analysis of accident cases selected during the initial analysis, the Anacapa analysts and researchers from the USASC and the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) identified specific aircrew coordination errors and developed a system for classifying the errors.

Results

During the initial analysis, aircrew coordination errors were rated as possibly contributing to 129 of the 369 human error accident cases reviewed. The more detailed analysis identified 84 separate crew coordination errors in 76 of these accidents. The analyses showed that accidents caused by aircrew coordination errors accounted for approximately 15% of all human error accidents and that the percentage had increased during the 6-year period that was examined. Aircrew coordination errors were 1.5 times more prevalent in night accidents than day accidents and frequently involved the task of obstacle clearance. The crew coordination errors were classified into six common problem areas: directing assistance, announcing decisions, using positive communication techniques, assigning responsibilities, offering assistance, and sequencing actions.

Utilization

The results of the accident data analysis were used in a follow-on project entitled "Development and Evaluation of an Aircrew Coordination Training Program" to develop a realistic tactical scenario that provided opportunities for crew coordination errors to affect performance. The accident data base analysis project is fully summarized in Thornton and Zeller, 1991.

Reference

Thornton, R. C., & Zeller, J. L., Jr. (1991, June). Aviation safety research. In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1990 annual summary report (Technical Report 930, pp. 47-54). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A241 134)

ARMY AVIATION AMMUNITION AND GUNNERY SURVEY

Dr. D. Michael McAnulty, Project Director

Purpose

This research was conducted to compile an empirical data base to describe the current attack aviation force, to formulate an accurate ammunition procurement request, to evaluate the training value of flight simulators for aerial gunnery, and to support revisions to the Army's aerial gunnery training programs.

Approach

Two questionnaires, Form A for aviators and Form B for unit commanders, were developed to collect data about Army aviation gunnery training. The questionnaires contained items about (a) the personal, military, and flight data about the respondent, (b) the suitability of current gunnery training publications, (c) the ammunition allocated and fired during fiscal year 1987 (FY87), (d) the utilization of gunnery range facilities, and (e) the utilization of flight simulators for gunnery training and qualification.

The survey was distributed to both active Army (AA) and National Guard (NG) attack aviators and unit commanders. The aviators returned 810 usable questionnaires (41% return rate) and the unit commanders returned 127 usable questionnaires (35% return rate).

Results

The questionnaire data were first used to describe the current attack aviation force. For example, the data indicated the AA aviators were relatively young and inexperienced. The NG aviators were older and more experienced, but they were maintaining their skills in aging and less effective attack aircraft. Another finding was that the average AA aviator flew slightly more than the minimum number of hours required to maintain his flying skills in FY87, but fired less than the authorized amount of ammunition. The average NG aviator logged fewer flight hours and fired less ammunition than his AA counterpart.

Five primary conclusions were drawn from the questionnaire data about Army aerial gunnery training during the period the survey was conducted. First, a substantial

number of attack helicopter units were unable to meet the training standards with the resources that are currently available to them. Second, gunnery ranges were not readily available to many units or had inadequate scoring methods. Third, flight simulators were being used only to a moderate extent by AA aviators for gunnery training. Fourth, a majority of the respondents agreed that standardized gunnery tables were needed to develop gunnery training programs, but the unit commanders wanted the flexibility to design training to meet the unit's mission requirements. Finally, the current ammunition authorizations approximated the minimum number of rounds needed to qualify and sustain the average aviator's gunnery skills.

This research project is fully summarized in McAnulty (1990) and is reported in detail in McAnulty and DeRoush (1988) and in McAnulty, Cross, and DeRoush (1989).

References

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McAnulty, D. M., & DeRoush, D. J. (1988, August). Army aviation ammunition and gunnery survey--Volume I: Executive summary (Research Report 1492). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A204 879)

AH-64 REFORGER SURVEY

Dr. D. Michael McAnulty, Project Director

Purpose

This project was designed to collect information about the effectiveness of assigning most AH-64 aviators to either the front seat (copilot-gunner) or the back seat (pilot). The project was also designed to collect information about the effectiveness of assigning AH-64 aviators to fixed crews.

Approach

A three-phase data collection approach was developed to collect the required information during a Return of Forces to Germany (REFORGER) exercise in September 1987. In Phase 1, a paper-and-pencil survey would be administered to collect information about the REFORGER participants' training and experience in the AH-64 and about their opinions about the training policies prior to the exercise. In Phase 2, structured interviews would be used to collect information about the aviators' experiences during the REFORGER sorties and to determine the types of optical system, crew coordination, and unit management problems that occurred. In Phase 3, a second paper-and-pencil survey would be used to collect information about the aviators' overall experience during REFORGER and to determine if that experience had changed their opinions about the most desirable training and management policies.

Work Completed

Three data collection instruments were developed and produced for the research effort. The pre-REFORGER survey contained 81 items divided into three parts. The structured interview schedule consisted of 66 items divided into five sections. The post-REFORGER survey consisted of 25 items divided into two parts. Finally, a research team prepared to travel to Germany to administer the surveys and interview schedule to the participating AH-64 unit. However, the 7th Army Training Command denied a theater clearance to the research team because the AH-64 fleet had been grounded pending the investigation of a recent accident and the correction of any contributing mechanical problems.

A brief report (McAnulty, Kaempf, & Blackwell) of the project activities was prepared and submitted to ARIARDA in

September 1987. The report included copies of the two
surveys and the structured interview schedule. The project
is summarized in McAnulty, 1988.

References

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McAnulty, D. M., Kaempf, G. L., & Blackwell, N. J. (1987,
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     Anacapa Sciences, Inc.

STUDY OF STAFF AVIATOR SKILL DECAY/REACQUISITION

Mr. Carl R. Bierbaum, Project Director

Purpose

This project was designed to collect data on the decay and reacquisition of flying skills of staff aviators prohibited from flying between March 1986 and February 1987.

Approach

The research was designed in three phases. In Phase 1, Anacapa Sciences, Inc. researchers were to develop the test procedures and the necessary data collection instruments for conducting the research. During Phase 2, evaluators were to monitor the commander's evaluation checkrides to collect data and administer a staff aviator questionnaire during the postflight debriefing. In Phase 3, the data collected during Phase 2 were to be analyzed and reported.

Work Completed

Three data collection instruments were developed for the research effort during Phase 1. A commander's evaluation gradeslip was developed to evaluate the initial performance levels of aviators. A practice iterations data sheet was developed to evaluate the flights required to retain aviators who did not perform to established standards. Finally, a staff aviator questionnaire was developed to obtain personal information from each aviator.

The Phase 2 data collection commenced on 3 March 1987 and was completed on 12 August 1987. Although there had appeared to be a large number of aviators who had not flown for a period of 1 year, data were collected on only 18 evaluation flights. The number of data collection flights did not provide sufficient data to perform a quantitative data analysis during Phase 3. Therefore, the research was terminated and the data collection forms were submitted to the Army Research Institute Aviation Research and Development Activity (ARIARDA). The project is summarized in Bierbaum, 1988.

Reference

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     Army Research Institute for the Behavioral and Social
     Sciences. (AD A199 906)

DETERMINATION OF ARMY RESERVE COMPONENT TRAINING REQUIREMENTS

Dr. John W. Ruffner, Project Director

Purpose

The objective of this project was to obtain demographic data and information about the adequacy of training requirements and training time for U.S. Army Reserve (USAR) aviators in the First Army area.

Approach

A survey questionnaire was developed and administered to First Army USAR aviators. The questionnaire assessed military and civilian demographic variables, adequacy of current training requirements, adequacy of the time allocated to meet the requirements, willingness to spend additional time to meet the requirements, and obstacles to training.

Results

The results of the questionnaire indicated that USAR aviators were generally satisfied with their civilian and USAR jobs, intended to stay in the USAR until eligible for at least a 20-year retirement, and considered the opportunity to fly, pay, and retirement benefits to be the most important retention factors. The aviators judged the time available to meet training requirements to be inadequate. In addition, the aviators judged that the unavailability of instructor pilots, an insufficient number of flight hours, the unavailability of training areas, and the unavailability of aircraft to be the major obstacles to meeting their training requirements.

This research project is fully summarized in Ruffner (1989). The results of the questionnaire are summarized in Ruffner and McAnulty (1987).

References

Ruffner, J. W. (1989, August). Determination of Army reserve component training requirements. In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1988 annual summary report (Technical Report 858). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A213 285)

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EVALUATION OF THE AVIATION RESOURCE MANAGEMENT SURVEY (ARMS) CHECKLIST

Dr. John W. Ruffner, Project Director

Purpose

The Aviation Resource Management Survey (ARMS) is a job performance aid used by the Army when performing inspections of active and reserve component units. The objectives of this project were to evaluate the content and organization of the ARMS checklist used by the First U. S. Army, to recommend improvements, and to develop a computer based information management system.

Approach

A preliminary review of the ARMS Checklist was conducted. Following this, criteria were developed for determining whether to add, delete, or modify checklist items. A survey questionnaire was developed and administered to subject matter experts in First Army National Guard and Reserve aviation support facilities and aviation units.

Results

The results of the survey indicated that the deficiencies described in the majority of the checklist items were detected easily during an ARMS evaluation visit and were moderately important for assessing the functional areas in which they were classified. The results also indicated that a facility or unit with the deficiencies described in the majority of the checklist items could support most aspects of its mission, assuming that the deficiencies exist in isolation. A set of decision rules was developed to aid the military user to determine if items should be retained in their present form, revised, or deleted from the checklist. An information data base was developed to summarize the checklist items' detectability, importance, and criticality ratings and to record the evaluations of reserve component units and facilities during future ARMS visits.

This research project is fully summarized in Ruffner (1990). The results of the ARMS Checklist evaluation are described in Ruffner and McAnulty (1989a; 1989b).

References

Ruffner, J. W. (1990, March). Evaluation of the aviation resource management survey (ARMS) checklist. In D. M. McAnulty (Ed.), <u>Human factors research in aircrew performance and training: 1989 annual summary report</u> (Technical Report 884). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A221 657)

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ANALYTIC ASSESSMENT OF ARTEP
TASK PERFORMANCE IN AIRNET

Dr. Beth W. Smith and Mr. Carl R. Bierbaum
Project Directors

Purpose

The objective of this research was to conduct a systematic assessment of the Army Training and Evaluation Program/Mission Training Plan (ARTEP/MTP) tasks that can be performed in AIRNET.

Approach

The analyses were divided into two phases: a composite mission development phase and a performability assessment phase. The composite scenario development identified the mission phases, segments, and functions for the Attack Helicopter Company ARTEP/MTP. Only the mission segments that are flight related or that can occur in a helicopter were included in the analyses. A 5-point rating scale, ranging from completely performable to not performable, was used to assess how well each task can be performed in the AIRNET device.

Results

Of 100 unique functions required to perform the composite mission, 77 were rated as at least partially performable in AIRNET. A rating of partially performable indicates that some major system requirements are not available or have limited operability, or that system performance is noticeably different from the aircraft. Six functions were rated as marginally performable, indicating that the functions could only be performed with a significant loss of realism. Seventeen functions could not be performed at all, primarily because of three missing system features: an automated target handover system, a remote laser designation capability, and a rocket weapon system. Six of the seven mission phases were rated as partially performable; only the Target Engagement phase was rated as marginally performable in AIRNET.

A report (Smith, Bierbaum, & McAnulty, 1990) on the analytic assessment of ARTEP tasks was prepared and submitted to ARIARDA on 1 August 1990. The approach and results of this project are summarized more fully in Smith (1991).

References

Smith, B. W. (1991, April). Effectiveness of AIRNET in training collective ARTEP tasks. In D. M. McAnulty (Ed.), Human factors research in aircrew performance and training: 1990 annual summary report (Technical Report 930, pp. 77-83). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A241 134)

Smith, B. W., Bierbaum, C. R., & McAnulty, D. M. (1990, July). An analysis of ARTEP task performance in AIRNET (Working Paper ARIARDA/ASI 90-02). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

DEVELOPMENT OF THE AH-64A DISPLAY SYMBOLOGY TRAINING MODULE

Dr. John W. Ruffner, Project Director

Purpose

The objective of this project was to develop a training module for AH-64A flight and weapon symbology. The training module was intended to be used by aviators during the AH-64A Aircraft Qualification Course and after assignment to an operational unit.

Approach

AH-64A subject matter experts (SMEs) were interviewed to identify performance deficiencies and to establish training objectives. Based on the SME interviews, the content and organization of the training module were determined and storyboards were developed. Following this, software was developed to deliver the material contained in the storyboards on a personal computer.

Results

The training module was designed to include a help system, tutorial lessons, and quizzes. Five tutorials and quizzes were developed covering position/movement, attitude/altitude, heading/navigation, cueing/reference, and weapon delivery symbology. Storyboards were developed for all five lessons and quizzes and computer programs were completed for the first two lessons and quizzes.

This research project is fully summarized in Ruffner (1990). The development of the training module is described in Ruffner, Coker, and Weeter (1989).

References

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    Sciences, Inc. (AD 213 456)

DEVELOPMENT OF THE BASIC MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE (MITAC)

Dr. Dudley J. Terrell and Mr. Gary W. Coker
Project Directors

Background

Traditional methods of low altitude navigation training have been unsatisfactory (e.g., Gainer & Sullivan, 1976). Therefore, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has conducted research to address the low altitude navigation training deficiency. In 1976, Anacapa Sciences, under contract to ARIARDA, developed the Basic Map Interpretation and Terrain Analysis Course (MITAC). The Basic MITAC used photographic slides and motion picture films of terrain features and map segments to teach low altitude navigation skills to helicopter pilots in a classroom format. Subsequently, the course was revised to an individualized training format. Holman (1978) demonstrated the effectiveness of the revised course by showing that Basic MITAC-trained student pilots navigated at twice the speed and with one-third the errors committed by traditionally trained aviators.

In 1979, Anacapa developed 13 cinematic exercises to provide supplemental training in map interpretation and terrain analysis over a range of geographic regions and climates. The exercises, termed the Advanced MITAC, were subsequently upgraded to a computer-based interactive videodisc format (Miles & LaPointe, 1986). Terrell (1989a) found that a significantly greater proportion of Advanced MITAC students than control (no MITAC) students had no deviations from the prescribed route during the posttraining navigation test.

Purpose

Compared to the Advanced MITAC exercises, the material and equipment for the Basic MITAC (e.g., 35 mm slides, booklets, projectors, tape players, etc.) were both difficult to use and unsuitable for computer-based training. Therefore, the purpose of this research area was to develop a videodisc/computer-based Basic MITAC to serve as a prerequisite to the Advanced MITAC and for use in the ARIARDA research program. In the first of two projects, the material from the original Basic MITAC was compiled and upgraded for videodisc development. In the second project, courseware was developed for use with the videodiscs and a microcomputer.

Work Completed

Basic MITAC Videodisc Development

The development of the Basic MITAC videodiscs has been completed. Anacapa Sciences researchers composed the narrative for the Basic MITAC, selected video material to supplement the narrative, and developed a script containing the narrative and instructions for taping the narrative and video material. Subsequently, Video Technics of Atlanta, Georgia, recorded the narrative on audio tape, generated the computer graphics and animation, digitized the video material, edited the video material on 3/4-inch videotape, and dubbed the audio and video onto a 1-inch master videotape. Finally, Optical Recording Project/3M in St. Paul, Minnesota, generated a master videodisc from the master tape and produced videodisc copies from the master videodisc. For more information about this project, see Terrell (1989b).

Instructional Software Development

In the second project, two experimental software programs were designed and developed for presenting edited information from the Basic MITAC videodiscs. One program was developed for dual-screen viewing of the videodisc contents. One monitor displays program instructions and content menus and the second monitor displays video from the videodisc player. The dual-screen program was loaned to the NASA Ames Research Center to use in research on emergency medical service flight navigation.

A second program was developed for use with a single switching monitor and a special video overlay card. The single-screen program was field tested in the HS-1 Strike Rescue Course at the Naval Air Station in Jacksonville, Florida.

References

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TRAINING EFFECTIVENESS OF AVIATION PART-TASK TRAINERS

Dr. Dudley J. Terrell and Mr. Gary W. Coker
Project Directors

Background

Many aviation tasks, procedures, and skills are trainable with the use of simulators and part-task training devices. Researchers at the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) have identified several operational training problems at the U.S. Army Aviation Center and have developed prototype training devices to address these problems (e.g., Miles & LaPointe, 1986a, 1986b; Ruffner, Coker, & Weeter, 1989; Terrell & Miles, 1989). The prototype training devices were designed (a) to remediate existing training deficiencies and (b) to be used in computer-based instructional strategies research at ARIARDA.

Purpose

The objective of this research area was to evaluate the effectiveness of the prototype training devices and instructional strategies developed at ARIARDA.

Approach

Three projects were conducted in this research area. In the first project, a plan of research was developed to maximize the generality of results from experiments with the Advanced Map Interpretation and Terrain Analysis Course (MITAC), the Modernized Cobra Preflight Inspection Trainer, and other prototype training devices developed by ARIARDA. The second and third projects evaluated the effectiveness of the Advanced MITAC and Preflight Inspection trainers.

Work Completed

Development of a Part-Task Training Effectiveness Research Plan

Researchers at ARIARDA and Anacapa Sciences developed an integrated research plan, which was organized around three categories of training effectiveness research questions.

First, how can aviation skills be trained more effectively
with a microcomputer than with current training methods?
Second, what is the best performance taxonomy for conducting
aviation part-task training research? Third, how do
variations in external conditions affect the performance of
aviation tasks?

Advanced MITAC Interactive Videodisc Training

An experiment was conducted to evaluate the training
effectiveness of the Advanced MITAC trainer and to compare
the effects of two methods of computer-based error
remediation on inflight navigation performance. The results
suggest that the Advanced MITAC is effective for teaching
contour-level navigation skills to helicopter pilots and that
computer-generated error remediation is more effective than
student-generated remediation. The results of this project
are summarized in Terrell (1990b) and are reported in detail
in Terrell (1989). The project is also reported in Terrell
(1990a).

In February 1989, the dual-screen version of the
Advanced MITAC was delivered to the NASA Ames Research Center
at Moffett Field, California, for field testing in an
emergency medical service flight navigation program. In July
1989, a set of Advanced MITAC videodiscs, software, and
computer equipment was delivered to the Naval Air Station in
Jacksonville, Florida, for field testing in the HS-1 Strike
Rescue Course at Jacksonville.

Modernized Cobra Preflight Inspection Trainer

The Preflight Inspection Trainer videotape was converted
from a videotape format (Miles & LaPointe, 1986b) to a
videodisc format and related courseware was designed and
programmed. Software was developed for dual-screen and
single-screen viewing of the videodisc contents (see Terrell,
1990b). The single-screen version of the training program
was field tested in the flightline classrooms of the AH-1
Aviator Qualification Course at Fort Rucker, Alabama.

References

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SURVEY OF RESEARCH IN COMPUTER-BASED INSTRUCTIONAL STRATEGIES

Dr. Dudley J. Terrell, Project Director

Purpose

Developments in computer-based instruction (CBI) promise to increase training effectiveness by capitalizing on the efficiency of the individual learning process while reducing instructor time. However, systematic experimentation is needed to identify the most efficient mix of technology and training method. This project was designed to survey the research literature in CBI training strategies and to organize the literature to support the development of a comprehensive plan for CBI research in aviation training.

Approach

This project was conducted in three phases. In Phase 1, a comprehensive survey of the published research on computer-based instructional strategies was completed and entered into a data base. In Phase 2, the research results were evaluated for their applicability to computer-based instructional design. In Phase 3, a list of questions was generated to guide research in CBI and a report was prepared to document the results of the project.

Results

The data base of CBI research (Phase 1) was developed during the second and third contract years. The research was evaluated (Phase 2) and the results documented (Phase 3) during the third contract year (Terrell, 1990a). Much of the work described in the CBI literature is the simple application of recent hardware and software improvements to existing training programs. The review indicated that the guidelines and research in computer-based instructional strategies are characterized by contradictions. CBI guidelines published by different authors frequently disagreed with each other and, in some cases, the guidelines contradicted the empirical data. Only 5 of the 57 guidelines identified were strongly supported by empirical data.

The project is fully summarized in Terrell (1990b).

References

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(AD A221 657)

BACKWARD TRANSFER AND SKILL ACQUISITION IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

Dr. George L. Kaempf, Project Director

Purpose

This project was conducted as a preliminary step in preparation for forward transfer-of-training research on the effectiveness of the AH-1 Flight and Weapons Simulator (FWS). The objectives of the two experiments conducted in this project were (a) to determine the proficiency of AH-1 aviators during their initial exposure to the FWS and (b) to measure the rate at which operational unit aviators acquire proficiency on selected maneuvers in the FWS.

Approach

In the backward transfer experiment, 16 AH-1 instructor pilots (IPs) were first administered a checkride evaluation on eight emergency touchdown maneuvers (ETMs) in the aircraft. The aviators were then evaluated performing the same ETMs in the FWS under conditions that were simulated to match the aircraft conditions.

In the skill acquisition experiment, three groups of 10 operational aviators each performed 10 iterations of 5 different maneuvers in the FWS pilot station. The 15 maneuvers included the 8 ETMs examined in the backward transfer experiment and 7 standard contact maneuvers. A fourth group of 10 aviators practiced a subset ($n = 5$) of the 15 maneuvers in the copilot/gunner (CPG) station. Two Standardization IPs evaluated the aviator's performance on each iteration.

Results

The IPs were not able to perform the eight ETMs nearly as well in the FWS as they did in the aircraft. Performance was rated as very poor on 82% of the FWS trials but only 27% of the aircraft trials. In addition, 44% of the FWS trials terminated in a crash. The IPs attributed their performance difficulties in the FWS to its visual system and control handling characteristics.

Initial performance was also poor on all maneuvers in the skill acquisition experiment, but the aviators did show

significant improvement across 10 training trials on all but four of the maneuvers (all ETMs). The average number of trials required to reach proficiency ranged from 9 to 28.

The method and results of this research project are fully summarized in Kaempf (1986) and are documented in Kaempf, Cross, and Blackwell (1989).

References

Kaempf, G. L. (1986, February). Research on the use and benefits of flight simulators for training field unit aviators. In K. D. Cross and S. M. Szabo (Eds.), Human factors research in aircrew performance and training (Final Summary Report ASI479-080-86, pp. 39-60). Fort Rucker, AL: Anacapa Sciences, Inc.

Kaempf, G. L., Cross, K. D., & Blackwell, N. J. (1989, August). Backward transfer and skill acquisition in the AH-1 Flight and Weapons Simulator (Research Report 1537). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A213 432)

TRANSFER OF TRAINING IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR FOR EMERGENCY TOUCHDOWN MANEUVERS

Dr. George L. Kaempf, Project Director

Purpose

This project was conducted to determine the effectiveness of the AH-1 Flight and Weapons Simulator (FWS) for training emergency touchdown maneuvers (ETMs).

Approach

A transfer-of-training paradigm was used to determine if ETM skills could be reacquired in the FWS and whether those skills would transfer to the AH-1. Twenty AH-1 aviators were first administered checkrides in the aircraft and in the FWS on ETMs they were prohibited from practicing because of safety considerations. A control group of 10 aviators were trained to proficiency on five ETMs in the aircraft and then given a second checkride in the FWS. An experimental group of 10 aviators were trained to proficiency on the five ETMs in the FWS and then in the aircraft.

Results

Most of the aviators were unable to perform the ETMs safely on the initial checkride. That is, the prohibition against practicing the ETMs had resulted in a loss of minimal proficiency. The control group aviators required relatively little aircraft training (approximately 6 trials) to regain proficiency on each ETM. The experimental group aviators required more extensive training (approximately 13 practice iterations) to perform each ETM satisfactorily in the FWS.

Prior FWS training did reduce the number of trials required for the experimental group aviators to reach proficiency in the aircraft (approximately 3 trials), indicating a positive forward transfer of training. However, none of the experimental group aviators were able to perform any of the ETMs on the first trial following FWS training. The last two findings show that FWS training can facilitate ETM training in the aircraft but cannot replace it entirely. Finally, the control group aviators did not perform satisfactorily on the second FWS checkride after being trained to proficiency in the aircraft. The lack of backward transfer indicates that the skills required to perform the

ETMs in the AH-1 aircraft are not the same as those required in the FWS.

The method and results of this research project are fully summarized in Kaempf (1988) and are documented in Kaempf and Blackwell (1990).

References

Kaempf, G. L. (1988, August). Utilization/effectiveness of flight simulators for field unit training. In T. B. Aldrich and D. M. McAnulty (Eds.), Human factors research in aircrew performance and training: Annual summary report (Research Note 88-81, pp. 93-105). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A199 906)

Kaempf, G. L., & Blackwell, N. J. (1990, June). Transfer-of-training study of emergency touchdown maneuvers in the AH-1 Flight and Weapons Simulator (Research Report 1561). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A226 360)

PREVIOUS YEARS' TECHNICAL ADVISORY SERVICES

During the previous four contract years, Anacapa Sciences personnel provided technical advisory services to 18 research and development projects that were directed by the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) or other Army organizations. The technical advisory services included subject matter expert consulting, acquiring and maintaining electronic equipment, computer programming, human factors design consulting, data collection and processing, and research design and analysis consulting.

Four of the technical advisory services (Evaluation of the AIRNET Simulator, Training Effectiveness of the AH-64 Combat Mission Simulator (CMS) for Conducting Crew Gunnery Initial Qualification Training, Training Effectiveness of the AH-64 CMS for Conducting Crew Proficiency Sustainment Training, and Accident Scenario Training) later became Anacapa research projects and are summarized elsewhere in this report. The following list identifies the remaining 14 technical advisory services in the order of their initiation:

- Support to Multitrack Testing,
- Light Helicopter (LHX) Crew Complement Issues,
- LHX Simulation Requirements,
- Support to the Special Operations Aircraft (SOA) Program Management Office,
- AH-64 Airborne Target Handover System (ATHS) Modification,
- Workload Applications to ATHS,
- Evaluation of the Rockwell-Collins ATHS Engineering Change Proposal,
- Quality Control of Revised Flight Aptitude Selection Test Score Sheets,
- Support to the Threat Part-Task Trainer,
- Support to the Night Vision Goggles Evaluation,
- Handedness and Flight Training Performance,
- Software Development for Flight Line Research Systems,
- Support to Operator Workload (OWL) Research, and
- Support to the Complex Cognitive Attributes Battery.

SUBCONTRACTS

Dr. Kenneth D. Cross, Subcontract Monitor

During the 5 years of the contract, 15 subcontracts and 2 purchase orders were completed by six different research organizations. Ten of the subcontracts were completed by Dynamics Research Corporation (DRC) during the current contract year. The numbers, titles, research organizations, performance dates, and reports, if any, of each subcontract are described in the following paragraphs. The subcontracts and purchase orders are described in the order they were awarded.

Subcontract number 690-87-1 was entitled "Stress, Tunnel Vision, and Decision Making." This subcontract was performed by the University of Alabama between May and December 1987. Runcie and Neggars submitted a subcontract report under the same title in January 1988.

Purchase order 690-1-TA was performed by the University of Alabama between January and February 1988. Under this purchase order, Dr. J. Dudgeon reviewed design issues for the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) Variable Complexity Flight Simulator.

Purchase order 690-2-TA was performed by Bynon and Associates between June and July 1988. Under this purchase order, Bynon and Associates developed software for the ARIARDA flight line research system (Form 168 V2.0 Technical Documentation).

Contract number 690-3 was entitled "Simulator Complexity Test Bed (SCTB) Program." Between November 1989 and May 1990, Evans & Sutherland developed and delivered one photo-based modeling system and a digitizing camera with a VAX 3520 for the SCTB program.

Subcontract number 690-90-2 was entitled "Modification and Upgrading of UH1TRS Low Cost Simulation Testbed to Support Training Research with Army Aviators." Between March and December 1990, personnel from the University of Alabama evaluated the deficiencies in the current UH1TRS aerodynamic model and developed a plan to correct them. This subcontract is summarized in Cross (1991b).

Subcontract number 690-90-3 was entitled "Development of a Methodology for Measuring Both Conscious and Subconscious Aspects of Aircrew Coordination in Army Helicopter Operations." Klein Associates, Inc. completed this

subcontract between April and October 1990. A report entitled "Observing Team Coordination Within Rotary-Wing Aircraft Crews" was submitted by Thordsen, Klein, and Wolf in September 1990. This subcontract is summarized in Cross (1991a).

Subcontract number 690-90-4 was entitled "Support ARI Training Research Simulator." Charles River Analytics, Inc. completed this subcontract between May and September 1990. They designed foundations for the automated hover trainer and reviewed helicopter models and the computational platforms for the Training Research Simulator.

Subcontract number 690-90-5 was entitled "Data Analysis and Instrument Improvement Measures of Crew Coordination." DRC performed this subcontract between October 1990 and April 1991. DRC submitted a report (#E-17639U) entitled "Results of the Data Analysis Army Aircrew Coordination Measures Testbed Conducted Spring 1990" in April 1991.

Subcontract number 690-91-1 was entitled "Manpower Estimate Report (MER) Procedures and Manpower Requirements Development." DRC performed this subcontract between January and September 1991. They submitted a report (#E-18818U) under the same title in September 1991.

Subcontract number 690-91-2 was entitled "Support for HARDMAN III Demonstrations." DRC performed this subcontract between March and June 1991. Under this subcontract, DRC personnel assisted in demonstrating the HARDMAN III suite of tools to potential users.

Subcontract number 690-91-3 was entitled "Extension and Application of the Blueprint of the Battlefield." DRC performed this subcontract between March and August 1991. They submitted a report (#E-17747U) entitled "Extension and Application of the Blueprint of the Battlefield - Task 1: Summary of Applications" in April 1991.

Subcontract number 690-91-4 was entitled "Manpower Estimates Report (MER) Integration." DRC performed this subcontract between March and October 1991.

Subcontract number 690-91-5 was entitled "Force Development Analysis (FORCE) and Soldier Characteristics Availability Database (SCAD)." DRC performed this subcontract between March and December 1991. They submitted four reports to Anacapa Sciences during this subcontract: "FORCE Design Specifications" (#E-17744U) in April 1991, "Prototype Maintenance Database for Patriot" (#E-17856U) and "SCAD Design Specification" (#E-17855U) in May 1991, and

"Maintenance Database for Patriot" (#E-17954U) in June 1991.
In December 1991, DRC also submitted four deliverables to Mr.
Judah Katznelson of the U. S. Army Research Institute: FORCE
final software (#E-19293U), SCAD (Phase I) final software
(#E-19294U), FORCE User's Guide (#E-19218U), and Technical
Report #E-19295U.

Subcontract number 690-91-6, entitled "Technical
Assessment of Helmet-Mounted Display Symbology for the ANVIS
Night Vision Goggles," was performed by DRC between June and
December 1991. DRC submitted three reports under this
subcontract, all authored by Morey and Simón (1991a, 1991b,
1991c). The first report (#E-18982U), entitled "Feasibility
Study for Improving the Training Research Simulator and for a
Computer-Administered Test Battery for Pilot Selection," was
submitted in October 1991. The second report (#E-19298U) was
entitled "Attention Factors Associated with HUD and HMD
Systems" and the third report (#E-19312U) was entitled
"Development of Handedness and Eye Preference Assessment
Instruments for ANVIS/HUD Research Applications." The last
two reports were submitted in December 1991.

Subcontract number 690-91-8 was entitled "Conduct
Research on Unit Structure and Technology Impact." DRC
performed this subcontract between July and December 1991.
They submitted four reports to Anacapa Sciences during this
subcontract. The first report (#E-18164U), entitled "Unit
Structure and Technology Impact, Task 1 Report: Types of
Army Units," was submitted in August 1991. The remaining
three reports, "Unit Design and Technology Impact, Task II
Report: Design of Army Units" (#E-18981U); "Unit Design and
Technology Impact, Task III Report: Analysis of Army Unit
Design" (#E-19313U); and "Unit Design and Technology Impact,
Task IV Report: Extending MANPRINT Analysis to Unit Design"
(#E-19314U) were submitted in December 1991.

Subcontract number 690-91-9 was entitled "Develop an
Automated Version of the Blueprint of the Battlefield
(AutoBOB)." DRC performed this subcontract between July and
December 1991.

Subcontract number 690-91-10 was entitled "Comanche
Aviation Manpower Requirements and O&S Cost Analysis
Support." DRC performed this subcontract between July and
November 1991.

References

Cross, K. D. (1991a, June). Development of a methodology for measuring both conscious and subconscious aspects of aircrew coordination in Army helicopter operations. In D. M. McAnulty (Ed.), <u>Human factors research in aircrew performance and training: 1990 annual summary report</u> (Technical Report 930, pp.103-106). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A241 134)

Cross, K. D. (1991b, June). Modification and upgrading of the ARIARDA UH-1 Training Research Simulator (UH1TRS). In D. M. McAnulty (Ed.), <u>Human factors research in aircrew performance and training: 1990 annual summary report</u> (Technical Report 930, pp.97-101). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A241 134)

Morey, J. C., & Simon, R. (1991a, October). <u>Feasibility study for improving the training research simulator and for a computer-administered test battery for pilot selection</u> (Report #E-18982U). Wilmington, MA: Dynamics Research Corporation, Inc.

Morey, J. C., & Simon, R. (1991b, December). <u>Attention factors associated with HUD and HMD systems</u> (Report #E-19298U). Wilmington, MA: Dynamics Research Corporation, Inc.

Morey, J. C., & Simon, R. (1991c, December). <u>Development of handedness and eye preference assessment instruments for ANVIS/HUD research applications</u> (Report #E-19312U). Wilmington, MA: Dynamics Research Corporation, Inc.

Runcie, D., & Neggars, J. (1988, January). <u>Stress, tunnel vision, and decision making</u> (Report Number SubTR690-01). Tuscaloosa, AL: University of Alabama.

Thordsen, M. L., Klein, G. A., & Wolf, S. (1990, September). <u>Observing team coordination within rotary-wing aircraft crews</u> (KATR9002-90-05-Z). Yellow Springs, OH: Klein Associates Inc.